This Thesis, "This Is Not Brain Surgery: Increasing Neurosurgical Knowledge and Retention in Medical Students", presented by Carl Gustaf Stefan Axelsson, and Submitted to the Faculty of The Harvard Medical School in Partial Fulfillment of the Requirements for the Master of Medical Sciences in Medical Education has been read and approved by:

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Date: April 20, 2018

This Is Not Brain Surgery: Increasing Neurosurgical Knowledge and Retention in Medical Students

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A Thesis Submitted to the Faculty of

The Harvard Medical School

in Partial Fulfillment of the Requirements

for the Degree of Master of Medical Sciences in Medical Education

Harvard University

Boston, Massachusetts.

May 7, 2018

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This Is Not Brain Surgery: Increasing Neurosurgical Knowledge and Retention in Medical Students

Abstract

The high-pressured neurosurgical working environment, where the majority of the physicians' time is spent in the operating room, leaves little time for teaching medical students. Yet, neurosurgical care and diagnosis is a field in which all medical students should be trained to an appropriate level, whatever specialization they choose to pursue as clinicians after graduating from medical school.

After extensive literature review, this study created and implemented a two-week asynchronous, video-based curriculum for four key topics in neurosurgery (Intracranial Hemorrhage, Neuro-Imaging, Hydrocephalus and The Glasgow Coma Scale) for groups of Harvard Medical School MD-students in the Surgery Core Clerkship and Neurology Clerkship at the Massachusetts General Hospital. Knowledge and self-efficacy pre- and post-test scores were recorded and analyzed, and compared to collected learner analytics (e.g. number of views).

Students who engaged with the curriculum significantly improved their knowledge test scores in all four content areas examined. The students who did not engage with the curriculum did not improve their knowledge scores from pre- to post-test. All students enrolled in the study (compliant and non-compliant) significantly improved their content-related self-efficacy.

This study shows that a focused, asynchronous, video-based curriculum in neurosurgery has a significantly positive effect on knowledge and self-efficacy scores amongst undergraduate medical students.

Future studies will aim to expand upon the conclusions from this study, improve learner compliance, and analyze learner analytics in further depth. This curriculum represents a viable and cost-effective opportunity to create a national neurosurgery curriculum for medical students.

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Acknowledgements

This thesis would not have been possible without the help and advice of a number of inspirational and highly knowledgeable individuals.

I would like to express my deepest gratitude to my mentor and thesis supervisor, Dr Roy Phitayakorn. Your kind mannered support and unwavering guidance, from the first day of working with you to the submission of this thesis, has been humbling to me throughout. I am certain that you will continue to be a mentor and source of inspiration for both my clinical and academic career for many years to come.

My sincerest gratefulness is also dedicated to Dr William T Curry, Dr Deborah Rooney and Dr Traci Wolbrink, of my thesis committee. As leaders within your fields and medical education, your help and insightful suggestions throughout the thesis process have been of the greatest importance. I am honored to have been able to share this experience with you, and I hope to have the pleasure of working with you more in the future.

Dr Emil Petrusa, thank you for your invaluable advice and help with this study.

I am truly grateful to the clerkship directors, Dr Noelle Saillant, Dr Hatem Reda and Dr Isabel Arrilaga, for allowing me to run this study within their clerkships.

Evan Sanders and Julia King, without your kindness and professionalism, video production would not have been possible. You are truly amazing at what you do, and I wish I can work with you again in the future.

I would also like to thank the HMS Academy review board for being so helpful throughout the process.

My deepest gratitude also goes to Dr Jennifer Kesselheim and Ayres Heller. You always go above and beyond to run the most fantastic course, which I have had the pleasure to complete and sadly soon move on from.

Finally, I would like to dedicate this thesis to my dearest mother Dr Maria Lindvall Axelsson. She has been my inspiration since I was old enough to understand the meaning of the word. My wonderful family has always been the biggest of blessings, and without them nothing would be possible, or meaningful.

This work was conducted with support from Students in the Master of Medical Sciences in Medical Education program of Harvard Medical School. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard University and its affiliated academic health care centers.

Chapter 1: Background

1.1 Background

Is there room in medical school curricula for neurosurgery education?

Neurosurgery is a neglected subject in most medical schools' curricula in the United States and Europe, which may explain the universally lower student confidence with regards to identifying, managing, and appropriately referring/treating common neurosurgical conditions, as compared to other medical/surgical conditions.[1,2] The high-pressured neurosurgical working environment, where the majority of the physicians' time is spent in the operating room, leaves little time for teaching medical students. Yet, neurosurgical care and diagnosis is a field in which all medical students should be trained to an appropriate level, whatever specialization or field they choose to pursue as clinicians after graduating from medical school.[3] Thus, there is a great need for undergraduate neurosurgery education that could integrate within an already packed medical school curriculum.[4] The current status quo is that instructors and educators have the best intention to teach, and there is a great need to teach, but there is merely not enough time available to do so in a clinical setting. Indeed, it is possible that this represents the major 'equation of frustration' as medical and surgical educators.

The solution: A flipped classroom approach?

One potential solution would be to use elements of a flipped classroom-style of education system combined with video-based learning. With current technologies, most instructors are able to produce basic videos at their institution at a relatively low monetary and time cost. After an initial upfront effort of producing the videos, the videos can be re-used in curricula for several years with minor edits. Furthermore, a video-based curriculum allows asynchronous learning, i.e. learners can access the teaching in different locations, at different times, and at their own pace.[5] This asynchronous aspect is an important component of adult learning principles and may be particularly helpful in the context of neurosurgery, where the abovementioned hectic working environment and emphasis on spending time in the OR, leaves little time for didactic teaching of basic concepts to medical students. Indeed, there have been a number of studies showing that videos can not only improve knowledge at a level that is equivalent to a traditional classroom or lecture setting, but also be beneficial in other domains, such as self-efficacy, or learner confidence of performing an activity.[6]

Can video-based education be a viable solution to the 'equation of frustration'?

Video-based, asynchronous learning is an important topic in medical education, and some medical schools are switching to a flipped classroom approach (e.g. HMS Pathways), where high-quality videos and asynchronous material are essential components. Despite this change, there is a distinct lack of any large randomized, controlled studies in the medical education literature. However, beyond the realm of medicine and surgery, educators and researchers have been delivering, researching, and evaluating the effectiveness of videos as an educational intervention for many years.

In fact, some of the most-cited research studies on the topic of Video-Based Learning (VBL) date back to the 1960's.[7] These early studies demonstrated that using a combination of visual and auditory learning (in comparison to merely explaining a concept verbally), not only improved recall in subjects, but also increased the level of knowledge retention by several orders of magnitude.[7,8,9]

Since the inception of VBL, videos have been seen as a beneficial educational tool to present knowledge in a consistent and visually attractive manner to different groups of learners. However, the role of VBL as a component of modern education has become increasingly significant with the advent of new approaches to integrate VBL with innovative teaching methods (e.g. the flipped classroom) and technologies (e.g. online learning).

There has been a relatively large body of research evaluating different outcomes of VBL within different educational settings. In many cases, videos have been used as complement to traditional education (e.g. the classroom-based setting). Given its specific advantages, the usage of VBL may indeed have unique implications for both learners and educators.[10] Many of these specific advantages stem from the unique properties of the video medium itself. For example, many concepts are challenging to explain using only text and images (as is often the case in a lecture-based setting), and videos allow the instructor to interact with images and text in an entirely different manner.[11,12] In addition, videos have been shown to improve learners' attention, motivation, and learning outcomes (e.g. knowledge)[13] as well as align well with different 'types' of learners, especially those cherishing a more visual type of learning.[14] Furthermore, since the 1960's, technology has dramatically improved from only being able to watch static VHS-style videos. The creation of the internet, social media, smartphones, and video-editing capability, have all dramatically changed the way educators can create and distribute educational video-material, and utilize it both within and beyond the instructor-led classroom setting.[15,16] In their 'VBL Cognitive Map', Yousef and colleagues (2013) have summarized the research to date for VBL, and the focus of investigation (Figure 1).[6]

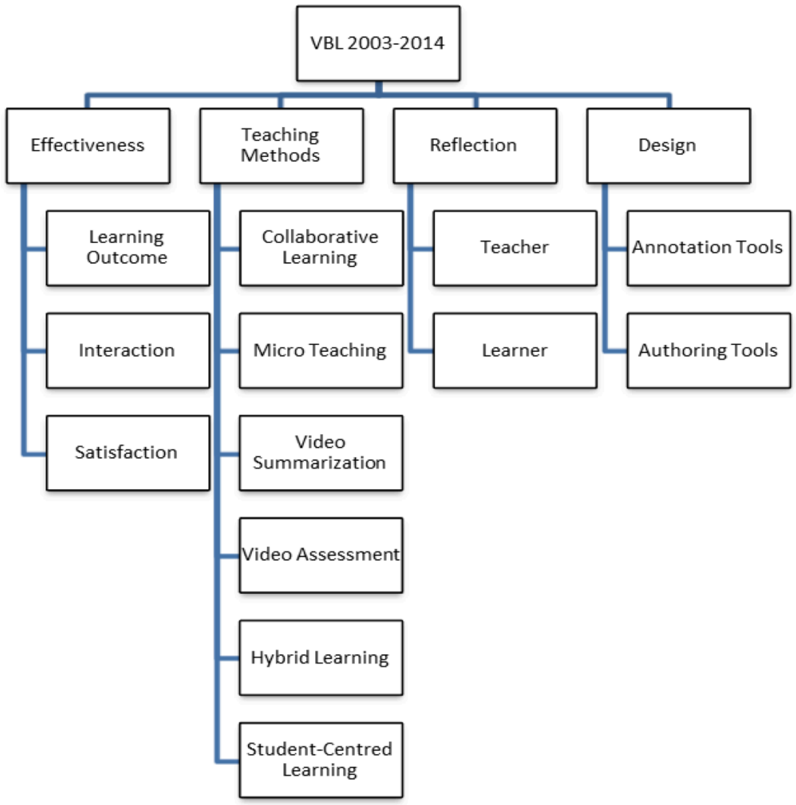


Figure 1. VBL Research Focus to Date: Cognitive Map[6]

For the purpose of this thesis, the focus has been placed upon learning outcomes as result of the VBL teaching process, e.g. knowledge and self-efficacy, as well as learning analytics. Previously, numerous general educational research studies have shown benefits in terms of achieving learning outcomes.[17] Balshev and colleagues (2005), showed statistically significant knowledge improvement when using a video-based curriculum, compared to controls using a text-based curriculum. In addition, user satisfaction was reported as highly favorable.[18] Lin and Tseng (2012) and Hsu and colleagues (2013), showed that K-12 students, who used a VBL-based curriculum to improve English language skills, performed significantly better than those who had a teacher-led curriculum.[19,20] However, as alluded to previously, there are also numerous studies described in literature that do not appear to show any additional educational benefit in terms of improved outcomes as compared to traditional teaching methods.[21,22,23] Hence, unlocking the true potential of VBL may involve coupling it with traditional teaching methods and providing a constructivist framework to engage learners so that they are more actively and independently involved in the learning process, rather than merely being 'spoon-fed' information.[6]

Creating effective videos

In addition to evaluating the outcomes of VBL in a variety of settings, much of the research on VBL to date has focused on understanding what factors increase the effectiveness of videos, in terms of on-screen design and structure. Research has demonstrated that many of the tools that are unique to the video-based environment, such as annotation and authoring tools, are also what helps leverage VBL to a level where it provides effective learning.[6] Being able to add notes, comments, or explanations to a dynamic medium helps improve the effectiveness of learning.[25] Annotation features are also useful beyond the video-production and editing stage, for students to use to make notes as they go through the learning material. In addition to this, other features such as authoring tools, opportunities to reflect, and collaborative tools, may all help to increase the effectiveness of a VBL curriculum. In the body of the general educational research community, the pivotal role of learning analytics has been emphasized as a way to improve the VBL process.[24] Indeed, learning analytics can help educators both understand factors affecting students that can be targeted to improve learning, and creating more effective videos.

In summary, a review of VBL in the general educational literature is slightly equivocal, but promising. In recent years, VBL has made an entry into medical education. Whereas the volume of research in medical education is not as significant, there have been several important studies looking at the outcomes described above.

VBL outcomes in medical education

As mentioned previously, there is a dearth of high-quality, randomized VBL trials in the medical education literature, as compared to the general educational literature. In general, some studies have demonstrated significant educational benefits of VBL, either as isolated learning experiences, or in conjunction with traditional teaching methods, such as lectures or seminar groups. [7,8]

A number of studies in medicine and surgery have looked at outcomes of various VBL interventions, many of which have been in a combined setting, i.e. in conjunction with didactic, face-to-face sessions. For example, in a study aiming to teach medical students the usage of ultrasound, Amini and colleagues (2014) showed significant improvements in both knowledge and confidence pertaining to performing ultrasound measurements for different causes of hypotension (e.g. pulmonary embolism).[26] However, no control group was included in this study. Several other authors also demonstrated improved knowledge and confidence with a VBL curricula, but also lacked a control group.[26,27,28]

Drummond and colleagues (2016) studied knowledge improvement regarding resuscitation guidelines in a group of pediatric residents after a VBL and simulation-based curriculum, comparing this to a cohort exposed only to traditional lecture-based learning with no simulation.[29] Whilst significant knowledge improvements were observed in the group of learners exposed to the innovative curriculum, as compared to those exposed to the traditional curriculum, the VBL/simulation course was criticized on the basis of being 24 times more expensive than the traditional lecture-only curriculum.[29] Despite the high cost, these results seem promising, but as this study looked at a combined simulation curriculum, it offers little evidence to the effectiveness of VBL as a standalone teaching methodology.
In addition to the issues with currently available research concerning the absence of randomized controlled trials, some studies have shown improvement in outcomes following VBL-based curricula, yet the measurement instruments of these outcomes have been inadequate. Klein and colleagues (2013) aimed to evaluate the impact of a 'facilitated video curriculum' on residents' abilities to screen and manage 'social determinants of health'.[30] Whilst this pre- and post-test study had a concurrent control group, and showed improved competence following a VBL-curriculum as opposed to no curriculum, this competence improvement was seen in a self-administered questionnaire, potentially introducing errors related to possible illusions of learning.

Similarly, in a pilot study, Hansen and colleagues (2011), aimed to study, whether instructional videos provided via an iPod® would improve and maintain knowledge levels and self-confidence levels amongst medical interns, regarding the insertion of male and female urinary catheters. After a pre-test, learners were given a 40-minute didactic session on urinary catheter insertion, followed by a post-test. After this, the intervention group was provided by a VBL-curriculum, and the control group was provided with no additional material. Three months later, a post-test showed, as expected, that those provided with the educational videos scored higher in both the knowledge and self-efficacy assessment.[31] However, again, whilst these results may show some merit of video-based learning as a method, the study effectively compared it to a group receiving no teaching at all.

Other groups have tried to study VBL, but the comparison groups did not receive equal amounts of instruction. For example, Ramachandran and colleagues (2017) aimed to make students competent in applying and correlating anatomy with clinical conditions.[32] They compared pre- and post-test knowledge tests between a group receiving videos, traditional lectures, and dissection with a group receiving only traditional lectures and dissection.[32] Whilst the study showed statistically significant improvements in knowledge scores in the intervention group compared to the control group, the comparison was essentially not analyzing the advantages of VBL in comparison to other teaching methods, but rather how VBL can be used as a useful teaching adjunct to traditional teaching.[32] This is an important finding in itself, but the 'controls' in this study were effectively not controls – they merely received less teaching, as they only received 2 out of 3 total types of teaching that were available in the study.

Similarly, Rowse and colleagues (2014) aimed to determine whether endocrine anatomy could be learned more effectively with the help of a surgical simulation curriculum in combination with a short video clip. The intervention group, who received the surgical simulation curriculum and the video scored significantly better on a post-test of knowledge, as compared to the control group, who only received the surgical simulation curriculum.[33] While the video may have been a key factor in approving these knowledge scores, the intervention group may also have received more instruction and thus subsequently scored higher in the knowledge test as compared to the control group.

In another study, Rowse and colleagues (2014) instead measured the impact of providing a short instructional Youtube®-video on Fine Needle Aspiration (FNA) on knowledge scores, in a final examination. The students who watched the videos performed significantly better in the final exam than the ones, who did not watch the videos. Students who did not watch the videos (ca. 50% of the group), stated 'lack of time' and 'lack of usefulness', as the key factors for their non-engagement.[34] Clearly, whilst this study showed the potential benefits of providing educational videos, it also showed the tendency for some students to not engage with voluntary learning material, despite obvious potential benefits. As Rowse and colleagues (2014) concluded, in additional to studying outcomes of VBL, future efforts should be targeted at improving the habits of self-directed learning amongst trainees, and evaluate actual 'long-term skill retention'. Therefore, the beneficial outcomes of video-based learning may not only applicable to learning of knowledge, but also in terms of procedural skill enhancement.[35,36,37,38,39]

There have been few studies that have investigated how videos, as a standalone curriculum, can improve learning. Mpotos and colleagues (2013) aimed to improve the Basic Life Support skills (BLS) in a group of medical students, and assigned groups of students to view videos only, voice-feedback only, or a combination of both videos and voice feedback-group, in a self-learning environment. This study showed that voice feedback and the combined curriculum, improved skills significantly, whereas videos alone only improved one (compression rate) of many aspects of BLS training.[40] This result reinforces the notion that further studies are needed to understand whether VBL is merely a potential supplement to traditional teaching methods, rather than a viable replacement in lieu of e.g face-to-face, lecture-based teaching. To that point, Srivastava and colleagues (2012) aimed to improve actual results, as well as comfort levels amongst medical practitioners, when performing pediatric lumbar punctures.[41] Subsequently, an instructional video on how to perform pediatric lumbar punctures was provided to a group of medical practitioners in the emergency department. Whilst the self-reported improved significantly after watching the videos, no increased rate of successful lumbar punctures was observed following the introduction of the instructional video.[41] Furthermore, in their study, Nousianen and colleagues (2008) aimed to investigate the benefits of learner-directed, interactive video training on suturing and knot-tying [42]. Students were randomly assigned to three practice scenarios: self-study with video, self-study with interactive video, and a combination of self-study, interactive-video, and additional expert instruction. No difference was seen between groups at the pre-test. All groups improved knowledge from pre-test to post-test to retention test, but no significant differences were detected amongst the three groups.[42] Similar results were seen in Jowett and colleagues' (2007) study, of providing a video-based curriculum on the one-handed square knot to a group of medical students.[43]

From literature, it seems that VBL is beneficial as a supplement to traditional learning. However, its role remains unclear as a substitute to other teaching methods. Clearly, further randomized controlled trials should be performed, to justify the current trend of switching to video-based, asynchronous curricula.

Self-efficacy improvement as an outcome of VBL

Self-efficacy beliefs are defined as ‘an individual’s beliefs about his/her capabilities to learn or perform at a defined level’.[44] Turan and colleagues (2012) have stressed the importance of studying and understanding self-efficacy within the context of medical education, for a multitude of reasons. These include leveraging achievement, improving independent learning and motivation, supporting learners with their learning, enhancing career development, and enabling social and emotional support to learners.[45] Furthermore, self-efficacy appears to be of paramount importance when examining the impact of new curricula, throughout medical and surgical education.[45] Evaluation of self-efficacy is important in any VBL studies as well.

Furthermore, from an innovation point of view, correlating knowledge with self-efficacy is also highly relevant. Relatively few studies have looked at how self-efficacy could be improved with the usage of VBL-based curricula. Randler and colleagues (2016) aimed to reduce negative emotions and increase self-efficacy of students, by exposing them to a pre-dissection video, prior to actual live dissection sessions.[46] The group who was exposed to a pre-dissection video showed improved self-efficacy at the three different times (before the dissection, after the video, and after the dissection), as compared to the control group.[46] Whilst the results from this study indicate similar promising potential qualities of VBL on self-efficacy, as the effects VBL had on knowledge, these effects may potentially only have been due to the additional teaching the intervention group received, as compared to the ‘control’ group. Clearly, additional studies are necessary to understand the effects of VBL on both self-efficacy and knowledge compared to other teaching methods, rather than merely in addition to traditional teaching. Rather intuitively, if students receive a higher volume of instruction, and more targeted teaching, the outcome effects will be higher.

Learner analytics and production costs with VBL

Finally, an important consideration described in literature, when introducing a new curriculum, is the practicality and cost-effectiveness of creating such a curriculum. Furthermore, the importance of using learning analytics has been studied in literature. The technical capabilities of modern software, allow researchers and educators to study a wide variety of metrics in relation to how learners use educational material, and subsequent assessment. For example, Mediasite® (Madison, WI), which was used in this study, allows the curriculum and assessment designers to study basic usage patterns (e.g. number of times viewed), to more advanced metrics (e.g. such as heat maps of activity, to correlate content with number of views). Chan and colleagues (2018) have reaffirmed the increasing need for educators to work with learning analytics as a conjugate to their teaching activities. As they argue, learning analytics are of paramount importance in education, to assist faculty in analyzing assessments and data, to 'inform decision making'. Furthermore, analytics can also be utilized to identify and explore 'system questions' and problems that may 'impact our educational programs'.[47] On a more basic level, learning analytics can be used to track compliance with the study and video-watching. However, in subsequent analyses and further studies, it can also be used to improve the curriculum development and video-creating process to ensure that we leverage the process to create optimally effective educational material.

Although VBL has higher upfront costs, it has potential savings if the curricula are repeated in terms of faculty time and the opportunity for faculty to earn clinical revenue in place of teaching. Maloney and colleagues (2015) studied the cost-effectiveness of a blended learning approach, compared to face-to-face learning, for evidence-based medicine training within a medical program.[48] In the face-to-face learning model, a group of students received ten two-hour classes. In the blended learning group, students received ten two-hour classes (with different activities), but with additional online and mobile learning opportunities (such as YouTube®). Incremental cost-effectiveness ratio showed that the blended learning approach was 24% cheaper than the traditional model, to reach the same level of knowledge of evidence-based medicine amongst the students. A break-even point was achieved within the 3rd year of the course (as there was transition cost involved with switching to a blended learning curriculum).[48]

In terms of learning analytics, several researchers have demonstrated that shorter videos (in the context of MOOCs), have higher viewer engagement; audience retention drops as videos become longer.[49-51] Also, as per Lau and colleagues (2017), longer videos are not associated with improved knowledge outcomes.[51]

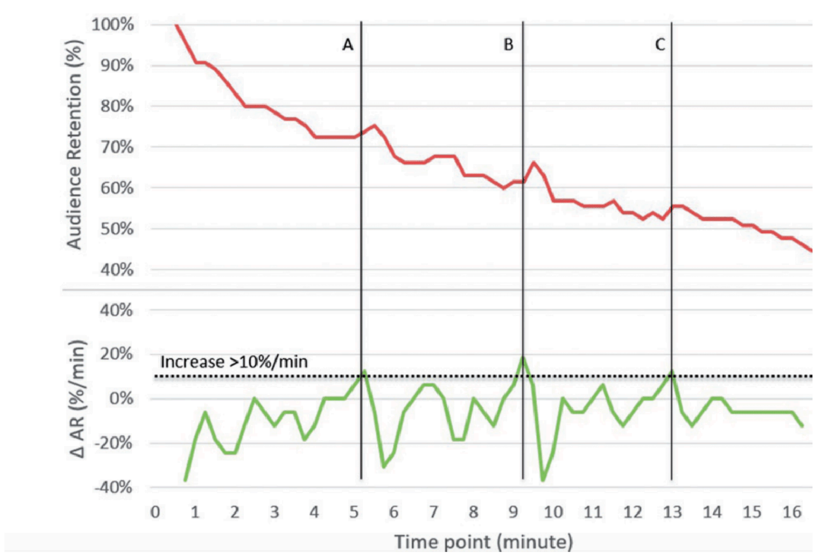


Figure 2. Audience retention with elapsed time in an educational video[51]

Setting the stage for this thesis: Why is neurosurgery relevant for medical students?

Given the high frequency with which patients with neurosurgical pathology present in general practice and the emergency room, and the increasing shortage of neurosurgical providers, Lobel and colleagues (2015) argue that the need for medical school curricula in medical schools is significant.[52] Furthermore, increased neurosurgery education is in the best interests of patients, as delayed neurosurgical diagnosis, even in a general practice setting, can have devastating consequences. Indeed, both United States and international data from trauma databanks and the literature indicate the rising incidence of neurosurgical cases presenting in primary care or the emergency room. For example, Gibbs and colleagues (2003) found that the symptoms of headaches represent 45 million visits to the physician every year, and 4.5% of all emergency room admissions, every year.[53] Furthermore, less than 20% of these patients presented to neurosurgeons or neurologists, but were typically managed in the primary care or emergency room setting.[53] As Lobel and colleagues (2015) discussed, circa one in a hundred of these headaches represents serious pathology, such as vascular pathology, hydrocephalus, or tumors.[52] Therefore a lack of competence in terms of diagnosis and basic management of these conditions, may lead to the eventual misdiagnosis, and mistreatment, of up to 500,000 patients every year, in the US.[54] Furthermore, subarachnoid hemorrhage is misdiagnosed in more than 10% of ER admissions, which significantly increases both the complication rate, and the 1-year mortality rate.[55] A recent study showed that head injury and subsequent complications (e.g. subdural, epidural, and subarachnoid hemorrhages) are often misdiagnosed, and there is huge variation in ordering CT scans in the ER (6.5% and 80% variation).[56] Delayed diagnosis because of no CT imaging increases the rate of complications at a tremendous rate. Similarly, more than 12 million patients visit emergency rooms with back pain across the US every year, which leads to both enormous morbidity because of delayed diagnosis, e.g. in cauda equina syndrome[52], and a significant medico-legal burden.[57]

Despite the obvious central role of neurosurgical knowledge for any physician working in a clinical frontline setting, a survey done in year 2000 amongst medical school deans, suggested that the common scenario in medical schools is for neurosurgical emergencies to be taught by internal and family medicine physicians.[58] At the same time, Fox and colleagues (2011), showed that 59% of medical school deans think neurosurgery is an unnecessary subject to be taught at medical schools. Therefore it is not surprising that a recent survey amongst graduating medical students carried out by Pilitis and colleagues (2013), showed that students feel very unprepared for diagnosing and managing neurosurgical disorders in clinical practice.[60] The survey results from their study, are summarized below in Figure 3.

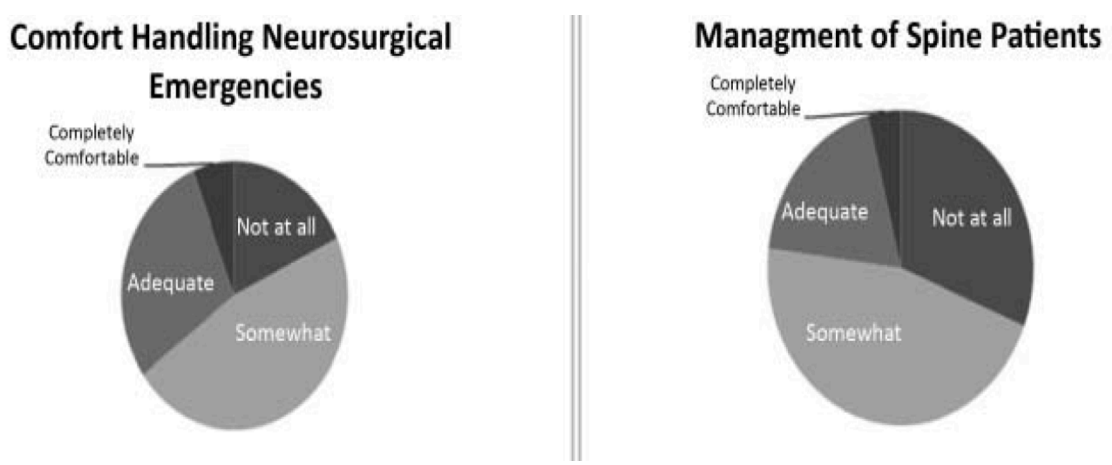


Figure 3. Medical students' self-reported comfort in managing acute neurosurgical and spinal conditions[60]

Figure 3 illustrates that only a small proportion of the medical students of the study reported comfort in handling neurosurgical emergencies and spinal patients. Given the importance of competence in these two areas of clinical practice for practitioners of a multitude of specialties, there is a great need for further educational effort to remedy this shortfall.

Why should videos be used in neurosurgery education for medical students?

In 1997, the American Association of Neurological Surgeons and the Congress of Neurological Surgeons submitted a petition to ask medical schools to include basic neurosurgery theory and common conditions in the medical school curriculum.[52] However, as of their review in 2011, and to date in 2018, no such curriculum has been implemented in any larger proportion of medical schools. As argued, there are a multitude of potential reasons for this, including the lack of neurosurgery questions in NBME issued general and subject exams. Specifically, neurosurgery topic questions only account for 1% of the focus of USMLE Step 2 and 3 questions, and 10% of surgery and neuroscience shelf exams.[52]

There is a mismatch between the lack of focus on neurosurgery in both medical school curricula, and USMLE and shelf exams, and the relative frequency of neurosurgical conditions with severe implications of delayed diagnosis and treatment. Therefore, this study aims to see whether a low-cost (in terms of money and time), focused, asynchronous, video-based curriculum could be a viable option for these problems. Thus, the research question and hypothesis of this study were formulated as below.

Research Question: Can a focused, asynchronous, video-based curriculum in neurosurgery at a medical school lead to better knowledge and self-efficacy amongst medical students?

Hypothesis: A focused, asynchronous, video-based curriculum in neurosurgery improve knowledge and self-efficacy scores amongst medical students, as measured by knowledge and self-efficacy, pre- and post-tests.

Chapter 2: Data and Methods

2.1 Short introduction

Setting the scene: Choosing the aims and objectives of the study

The significance of this research is multifold. Firstly, there is an unmet need of providing effective and engaging neurosurgical education to medical students and preparing them to deal with key neurosurgical conditions that they will encounter later in their careers. Indeed, educational concept videos may be a practical educational modality within the challenging neurosurgical environment. Secondly, the availability of high-quality, randomized controlled trials on the usage of educational videos within medicine/surgery is limited at best. Thus, the proposed research would not only contribute to the educational setting of teaching medical students about key concepts within neurosurgery, but also help to further our understanding of the educational impact of concept videos at large.

In order to develop practical aims/objectives and a well-aligned data collection and analysis strategy, a thorough and multi-dimensional needs assessment was performed. The initial basis for this assessment came from a literature review and empirical experience of the principal investigator.[52,60] Thus, although a needs assessment would be used to confirm this prior to proceeding with the main study, the core of the study was constructed around measuring the educational impact of high quality, video-based, asynchronous learning, on knowledge and self-efficacy. The aims and objectives of the study are summarized below in Figures 4-6 (see subsequent page).

Aim #1: To create a concept video curriculum for key neurosurgery/acute neurology concepts for Harvard Medical Students rotating through the 3rd year PCE surgery core rotation and 4th year neurology clerkship
Objective #1: To develop a series of focused concept videos on key neurosurgical/neurological concepts
Objective #2: To administer these videos in a defined/given curriculum format during the above rotations for students at Massachusetts General Hospital

Figure 4. Aim (1) of study and associated goals

Aim #2: To study the educational impact of using concept videos, as teaching tool in undergraduate neurosurgical/acute neurology education
Objective #1: To study the knowledge acquisition of an intervention (cross-over intervention) group that will be exposed to a series of concept videos on key neurosurgery/neurology concepts
Objective #2: To compare the knowledge acquisition of the intervention group (crossover intervention) to a control group, who will not be exposed to the concept video content (but exposed to learning objectives and references to written content), by using a knowledge test
Objective #3: To allow the control group access to the concept videos after a comparative study has been performed
Objective #4: To allow both the intervention group and the control group access to the learning objectives and reading material for all concepts
Objective #5: To distribute the concept videos through the Mediasite® e-learning interface
Objective #6: To analyze usage data and dynamics (e.g. number of views) of concept videos, by using the Mediasite® video platform analytics dashboard
Note. As this is a crossover intervention, half of the cohort will act as the control for two of the videos, and the intervention group for two of the videos, and the other half of the group, vice versa.

Figure 5. Aim (2) of study and associated goals

Aim #3: To study the self-efficacy following the use of concept videos, as a teaching tool in undergraduate neurosurgical/neurological education
Objective #1: To study the self-reported ratings of self-efficacy of students prior to, and after concept video intervention
Objective #2: To use this information gained from questionnaires to create further concept videos, if intervention proves effective and successful

Figure 6. Aim (3) of study and associated goals

Pre-Study Considerations and constraints

Prior to outlining the final design of this project, some practical considerations had to be taken into consideration. These concerned the choice of the intervention group, the timeline of the intervention, the delivery of the intervention, the assessment/evaluation of the effectiveness of the intervention, ethical issues within the study, and constraints concerning producing an intervention, evaluating it, and developing a thesis within the time period allotted for the purpose of the Master's degree.

The clerkships chosen for the study (PCE Surgery Core Clerkship and Neurology Clerkship, both at the Massachusetts General Hospital) were chosen after HMS Academy and clerkship director approval. Other clerkships were considered, but given the timing of the study, the schedule of clerkship rotations, and numbers needed for statistical significance, these two clerkships were considered best. The timeline for this study started on 12 July 2017, when the HMS Academy application was submitted. Upon HMS Academy approval (See Appendix C), focus groups were held with a convenience sample of Harvard Medical students. Also, the surgery and neurology clerkship directors were contacted to enroll their students into the study. Furthermore, given the busy and complicated schedule of the clerkships, much effort had to be employed into scheduling the study sessions (two face-to-face sessions of one hour each in each rotation/cohort, to deliver the pre- and post-test material).

Ethical considerations

As per the HMS Academy approval, participation in the study was completely voluntary throughout. This was explicitly made clear to all students, clerkship directors, and other faculty involved. Students were allowed to engage with the material to whatever extent they wished including not at all. No data concerning viewing statistics of the videos, test scores, or other feedback, were made available beyond the research group. Furthermore, all data was made anonymous for data analysis, with anonymous numerical identifiers allocated to each participant.

Study dropout, compliance, and power

Given the voluntary nature of the study, a level of drop out and non-compliance to the study was expected. As evidenced below, this level of dropout was taken into consideration in the statistical data analysis in SPSS® (Version 24, Chicago, IL).

In terms of estimating the required sample size for desired level of power (0.8), this was performed for the knowledge test based on literature[61] and indicative results from the piloting of the test. At 80% statistical power, with a two-tailed alpha value of 0.05 and a beta value of =0.2, the required sample size (for each sample separately (i.e. watched vs. not watched videos), would have to be 16.

Timeline: Design, approval, and execution of the study

With the considerations and constraints mentioned above, following deliberation with the assigned thesis committee, HMS Academy (IRB) approval, and collaboration with academic and clerkship directors in the Harvard Medical School (HMS) and the Massachusetts General Hospital (MGH) community, an approved needs assessment and study design was executed along with designation of the targeted groups of the proposed intervention. The timeline, from the initial conception of the idea to thesis submission, is outlined below in Figure 7.

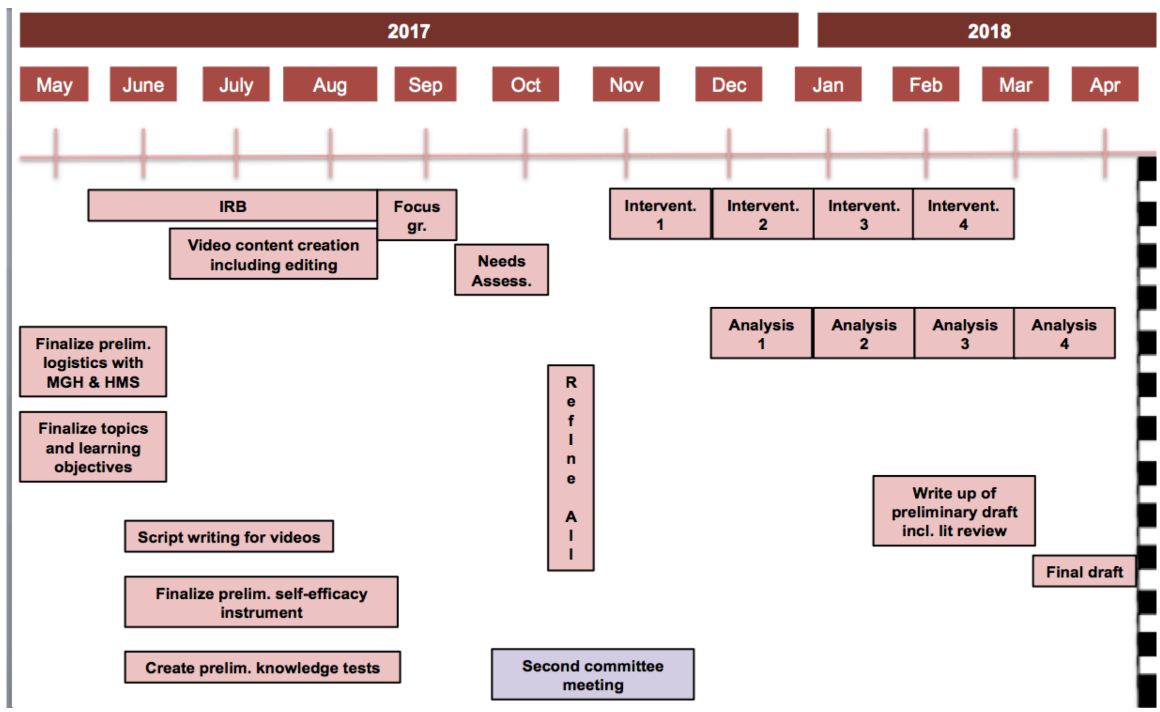


Figure 7. Timeline of study: HMS Academy/IRB approval, content creation, scheduling, intervention, data analysis, and write-up

Having outlined the preliminary study design, and upon approval of the study topic by the assigned thesis committee, the study design, development, and delivery commenced. This is described below, in 2.2 Materials and Methods.

2.2 Materials and Methods

Given the complexity of the study, the **Materials and Methods** section has been divided into distinct stages: pre-study, content creation, study, and post-study. Despite this evidently chronological, yet practical divide, many steps within these stages proceeded simultaneously, and fed back to each other to allow modifications and improvements to the study throughout.

Pre-study	**Content creation**
Study	**Post-study**

Pre-study: Initial planning

Prior to performing needs assessments, focus groups, content creation, and the main study, a suitable intervention through which the curriculum would be channeled through, had to be selected. These initial choices would be re-affirmed or changed, based on focus group discussion sessions, and a needs assessment survey.

Choosing an appropriate intervention modality

As described above, an asynchronous video-based education modality was selected for this study as it could be produced to a high quality, be standardized, and matched to a curriculum and learning objectives that were appropriate for medical student learners. As such, the videos were created (as described below, in Content Creation), according to the principles outlined in Mayer's Multimedia theories concerning the cognitive processes for meaningful learning.[62] Furthermore, as described above and below (see Literature Review and Background), prior work had established video-based, asynchronous curricula as effective and beneficial in similar settings.

Choosing what to measure

As evidenced by literature (see above), medical students experience a lower level of knowledge and self-efficacy in neurosurgery as compared to other topics in their curricula. As part of the content creation process (see below), modalities to test these two outcomes were designed specific to this study, given the lack of anything that could be adapted from in literature. Measuring knowledge not only requires clearly defined learning objectives (as those derived from the Congress for Neurosurgery (CNS) curriculum[63]), but also careful piloting to ensure an appropriate level of difficulty (i.e. desirable difficulty).

The modern technology back-end of hosting platforms of videos allows further learner analytics to be measured. A variety of metrics can be measured, ranging from basic user engagement (i.e. whether the study group watches their assigned videos), to the number of times watched, or the average time watched. The learning management system (LMS) for the videos for the purpose of this study (Mediasite®) allows this. Subsequently, in addition to measuring knowledge and self-efficacy outcomes, further analytics were included as part of data collection and analysis.

Choosing the topics

Neurosurgery is a broad sub-specialist topic, and subsequently, the availability of a specific neurosurgery needs assessments and measurements of medical student knowledge gaps were not available. However, the Congress of Neurological Surgeons (CNS) have outlined learning objectives for a neurosurgery curriculum for medical students.[63]

As per the CNS, the curriculum and learning objectives are divided into the following topics (with sub-topics in each):

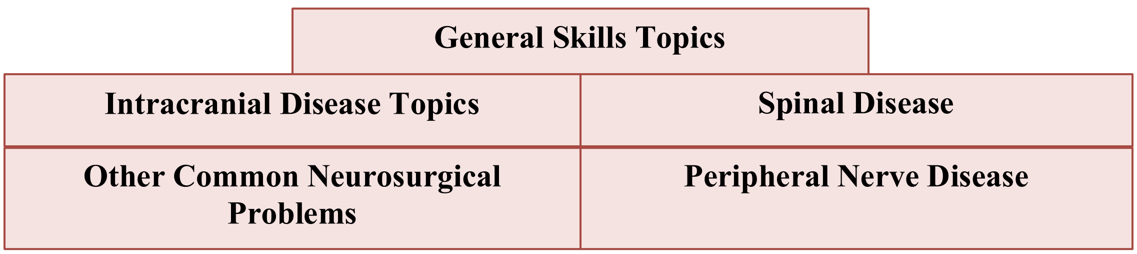


Figure 8. Topic areas of CNS curriculum[63]

These topics and learning objectives have been peer-reviewed by the CNS academic faculty, and they cover a wide range of common neurosurgical pathologies and core knowledge that is important for any medical practitioner.

After consensus amongst the researchers, and neurosurgical and non-neurosurgical faculty advisors, four sub-topics were chosen from the topic areas of the CNS medical student curriculum to be included in the pre-study work (as described below in Figure 9).

Intracranial Hemorrhage	**Hydrocephalus**
Neuro-Imaging	**The Glasgow Coma Scale score**

Figure 9. The four sub-topics chosen for video-based curriculum of this study

These topics were deemed to fulfill the relevance criteria for this study, which had been outlined based on the principles outlined by, regarding goal setting: SMART (Specific, Measurable, Achievable, Realistic, and Timely).[66] Using this framework in conjunction with the selection process was pivotal to the study, given the practical constraints and time-constraints described above. The framework of criteria developed for the selection of intervention topics for this study is outlined below.

Generalizability: Relevant to medical practitioners of all specialties and of all levels of seniority, for the entirety of their medical careers.

Mutually Distinct (Specific): Although the basic principles and pathologies may be related on a basic level, the topics are sufficiently distinct not to cause issues with subsequent data analysis.
Measurable: Given the time constraints and testing modality chosen to measure the effectiveness of the intervention (e.g. Multiple Choice Questions), the topics had to be appropriate for the likely format of measurement of results.
Practical and Appropriate (Achievable): Given the level of seniority of the medical students in the study group (2nd-4th year medical students at Harvard Medical School), prior lack of exposure to neurosurgery in the past, and likelihood of pursuing other non-neurosurgical specialties in subsequent specialty training, the topics had to be pertinent to a wide variety of clinical settings.
Realistic: The topics had to be specific and ring-fenced to the extent that mastery of content could be achieved at the given level of seniority and stage of clinical practice (i.e. medical students).
Time-bound: The topics chosen, and their outcomes measured, within the given time-frame of the study, and as appropriate and practical as possible, given the hectic schedules of the clinical clerkships at Harvard Medical School and Massachusetts General Hospital.

Choosing the learning objectives for each topic

The Congress of Neurological Surgeons' medical student curriculum outlines detailed learning objectives for each topic and sub-topic. These have been peer-reviewed to cover the essential knowledge, at the right level of difficulty, for undergraduate medical students.[63] However, as the scope of this intervention would be focused only over the course over a few weeks, specific learning objectives had to be selected based on the pre-study feedback from the informal group discussions with medical students from the target learner group, as well as the needs assessment survey (as described below). Similar to when choosing the appropriate topics for the intervention to target, the learning objectives also had to fulfill the criteria (based on S.M.A.R.T.), as described above.

Focus Groups and Needs Assessment

Having established a basic plan for the study and received the first approval to proceed from the thesis committee, an initial survey stage was carried out. In order to gauge the relevance and need for a) examining knowledge and self-efficacy, b) the chosen topics, and c) using videos and asynchronous learning as a teaching method, two informal, focus group-style, group discussion sessions were organized with student members of the HMS Surgical Society. These were convenience sampled, and after approval by the relevant Chairs of the Student Society, these discussions took place consecutively in two one-hour sessions, with seven students attending each session. These students were all part of the relevant learner group (Harvard Medical School MD-students). As per research protocol, these sessions were not recorded, confidential, and only informal field-notes were taken to note main points and comments. Open-ended, guiding questions were prepared beforehand, but discussions were free-flowing and exploratory. Using the guidelines developed by Leung and colleagues, (2009) expectations were clarified in the group, prior to the session.[64] An introductory email was sent out to the groups prior to the sessions, and this information was repeated at the onset of each session. As per Leung and colleagues (2009), and the Omni toolkit for conducting focus groups, the open-ended questions were developed to fall into five general categories.[64,65] Importantly, the majority of the discussion sessions were dedicated to exploring and examining these questions.[64,65] However, due to this being an exploratory pre-study stage, the facilitator (GA) was allowed to diverge from these if deemed relevant.

The questions used in the discussion groups are summarized below in Figure 10.

Opening Question	**Introductory Question**	**Transition Question**
Which year of medical school are you in? What are you currently studying in the curriculum?	Have you been taught any neuroscience, neurosurgery, or neuro-anatomy so far?	What would you like to know to feel more confident in dealing with neurosurgery cases?

Key Question	**Concluding**
How confident are you in the basics of: hydrocephalus, intracranial hemorrhage, neuro-imaging and the Glasgow Coma Scale Score?	Do you think students would find value in a video-based curriculum? Any final ideas?

Figure 10. Open-ended questions: Main Categories and Corresponding Questions (as adapted from Leung and colleagues (2009) [64,65]

After the informal discussion sessions, the field notes were discussed in the research group and main points were extracted. No formal thematic analysis was conducted as this was beyond the scope of the study, and not viable given time constraints. As summarized below (see Results), these main points pertained to a) the topic taught as part of the curriculum b) the metrics measured (i.e. knowledge and self-efficacy) and c) the acceptability of using multiple-choice questions and a modified self-efficacy, self-rating scale, as part of the intervention. Furthermore, some general points, pertaining to the qualities of effective asynchronous, video-based educational material were noted. Students were also invited to submit further ideas and feedback subsequent to the group discussion sessions via email. The second part of the needs assessment was in the form of a survey sent to a group of hospitalist physicians via email. This survey was done to ascertain and understand the attitudes and perceived need of primary care medical practitioners for an undergraduate curriculum in the basics of neurosurgery. Respondents (n=8) were also surveyed about their specific attitudes towards the potential topics chosen, and using videos as the modality through which this curriculum would be taught.

In addition to developing appropriately worded items, the number of items had to be considered. A brief literature review of the subject revealed that there is no clear, 'magic' number[67], so the intention was to develop the required number of items, to adequately assess the construct given its complexity, and the level to which it was desired to assess it.[67] The next step was to develop survey items that were unambiguously worded, and assessed the construct adequately. As per the evidence-based, best practices outlined by Magee and colleagues (2013), survey items were written as questions rather than statements, allowing construct-specific response questions.[67] Furthermore, between five to nine response options were included (as appropriate to the type of question), and questions were articulated in a manner to reduce possible bias.[67] The survey was piloted amongst a group of colleagues (n=3, resident physician, medical student, attending physician) to ensure it was of an appropriate length and complexity. No modifications were made, and the survey was next reviewed by fellow members of the Surgical Education group at Massachusetts General Hospital (n=2), the HMS Academy Review board (n=3), as well as non-neurosurgical colleagues of the medical profession. The questions in the final survey are displayed below in Figure 11 (full survey in Appendix A).

- During medical school, did you receive any formal training in neurosurgery?
- If so, approximately how many days of neurosurgery did you experience?
- Have you ever used concept videos (i.e. short educational videos) as a learner?
- How confident would you say that you are with the following concepts?
  - The pathophysiology and treatment of hydrocephalus
  - The pathophysiology and treatment of intracranial hematoma/hemorrhage
  - Recording and interpreting the Glasgow Coma Scale Score
  - Interpreting neuro-imaging (e.g. CT, MRI)
- It is essential for a clinician to have a basic understanding of...
  - The pathophysiology and treatment of hydrocephalus
  - The pathophysiology and treatment of intracranial hematoma/hemorrhage
  - Recording and interpreting the Glasgow Coma Scale Score
  - Interpreting neuro-imaging (e.g. CT, MRI)
- I would be interested in brief educational videos that review and consolidate the essentials of...
  - Hydrocephalus
  - Intracranial hematoma/hemorrhage
  - The Glasgow Coma Scale Score
  - Neuro-imaging

Figure 11. Needs Assessment Survey distributed to MGH Hospitalist Group

Upon approval of the Director of the Hospitalist group at Massachusetts General Hospital, the survey was distributed via email and sent out to the entire hospitalist group on 3 October

2017. Due to the time constraints involved, and the pre-study nature of this needs assessment, convenience sampling was considered appropriate. The survey was distributed using the Qualtrics ® software, and responses collected prior to commencing the main part of the study, and content creation. The data collected was analyzed using simple statistical measures available in the Qualtrics ® software, including frequencies and percentage agreements. No formal statistical analysis was conducted, as this was considered beyond the scope of this part of the study.

Proceeding to Content Creation and Main Study

Having established a basic needs assessment in the target population and beyond, as well as their attitudes concerning the educational topics, curriculum delivery modality, and assessment, the major task of creating the envisaged asynchronous, video-based curriculum in neurosurgery was initiated for the designated neurosurgical topics: Intracranial hemorrhage, Neuro-Imaging, Hydrocephalus and the Glasgow Coma Scale.

Content creation: An asynchronous, video-based two-week neurosurgery curriculum for clerkship medical students

The content-creation process included several steps and activities, as summarized below in Figure 12. These activities pertained to reviewing the most up-to-date literature on the four topics, outlining learning objectives, script-writing, video recording, production and editing, development of knowledge tests for each topic in the format of a multiple-choice test, and the development of a self-efficacy instrument specific to this study. Feedback was sought from senior advisors and supervisors throughout, to ensure alignment to the learning objectives and learner group, as well as accuracy of the material.

Figure 12. Content creation: Major activities

Outlining learning objectives

As described above, the Congress of Neurological Surgeons have outlined a number of learning objectives for these topics as part of their neurosurgery curriculum for medical students.[63] However, given the scope of the study, these had to be limited to a select number of three to four learning objectives for each video, to ensure a targeted scope of video content. In conjunction with thesis advisors from neurosurgery and non-neurosurgery faculty, these were chosen, and their wording was adjusted to ensure suitability, unambiguity, and specificity to the topics studied. The learning objectives for each of the topics and videos have been provided below in Figure 13-16.

- Recognize and initiate management of acute subdural and epidural hematoma, including surgical indications.
- Recognize and initiate management of subarachnoid hemorrhage.

Figure 13. Learning objectives for Video 1: Intracranial hemorrhage

- Recognize the symptoms and signs of hydrocephalus in children.
- Recognize the symptoms and signs of hydrocephalus in adults.
- Understand common etiologies of hydrocephalus in children and adults, and differentiate between communicating and obstructive hydrocephalus.
- Understand treatment strategies for hydrocephalus.

Figure 14. Learning objectives for Video 2: Hydrocephalus

- Differentiate on computerized images between blood, air, fat, CSF, and bone.
- Recognize specific disease entities listed below such as, epidural, subdural, intracranial hematoma, subarachnoid hemorrhage, brain tumors, and hydrocephalus.

Figure 15. Learning objectives for Video 3: Neuro-Imaging

- Understand the theoretical underpinnings of the Glasgow Coma Scale Score.
- Assign and interpret the Glasgow Coma Score.

Figure 16. Learning objectives for Video 4: The Glasgow Coma Scale

A neurosurgeon subject matter expert (WTC) reviewed the learning objectives. Subsequently, a literature review was carried out to explore the up-to-date educational literature to match the learning objectives, and a script for the videos was written.

Literature Review of Topics and Script Writing

Preceding the script writing stage, a thorough literature review was undertaken in order to define the appropriate resources to use for developing the curriculum. In order to match the level of information that is expected at a non-specialist level, the latest editions of the core neurosurgery textbooks were used as a baseline (see Appendix C). These textbooks were explored and information pertaining to each learning objective was summarized and rewritten in a scripted format in Word ® files. Open source figures and diagrams were identified at the literature review stage, and matched to the corresponding learning objectives. A neurosurgeon subject matter expert (WTC) subsequently reviewed the scripts, to ascertain factual correctness and a sufficient focus on the needs of the target group of learners.

Video Creation

Throughout the script writing and video production stage, Richard E. Mayer's principles of effective multimedia and video-based learning were utilized.[62] According to Dr. Mayer, three cognitive processes are at work to enable meaningful learning. These include selecting, organizing, and integrating.[62] Indeed, his research and guidelines were established to optimize those activities.[6] As described above, previous research indicates that learning is more effective using words and pictures, compared to merely using words.[62] However, in terms of creating high-quality, effective, video-based material, these principles have been elucidated further in this study. The research and subsequent guidelines for creating effective multimedia educational material center around three main goals of video production to enable ‘meaningful learning’.[62] These include ‘to reduce extraneous processing’, ‘to manage essential processing’, and ‘to foster generative processing’.[62] These principles have been summarized in Figure 17 below, with specific examples of how this was achieved in this study.

Reducing Extraneous Processing	1. Coherence principle 2. Signalling principle 3. Redundancy principle 4. Spatial contiguity principle 5. Temporal contiguity principle	• Only pertinent audio/visuals used • Highlighting main structures using marker • Limited written text – mainly audio+visuals • Visuals narrated with corresponding audio • Audio-visuals closely integrated on each screen
Managing Essential Processing	**1. Segmenting principle** **2. Pre-training principle** **3. Modality principle**	• Each major concept (e.g. GCS) sub-segmented • Concepts introduced with relevant clinical case • Extensive audio/narration used rather than text
Fostering Generative Processing	**1. Personalization principle** **2. Voice principle**	• Conversational-style narration used throughout • Friendly, yet commanding voice used

Figure 17. Mayer’s Multimedia Theory as applied to this study

After review of the above principles and other scholarly material on how to create effective educational videos, a PowerPoint® storyboard was created to match the written script. Additional animations were planned throughout the storyboard. The scripts with relevant annotations are included in the Appendix B.

Three planning sessions were carried out at the Harvard Medical School video studio, together with expert producers. The recording session started on 5 September 2017 and finished on 8 September 2017. Next, the researcher carried out further review of the material, and additional editing took place with feedback from select members of the thesis committee. A neurosurgery subject matter expert (WTC) also reviewed the videos to ensure factual accuracy and didactic rigor. Following the final review, the videos were uploaded onto Mediasite® and access was enabled to the relevant study population.

Test creation

The needs assessment and literature review also supported the appropriateness of using a Multiple-Choice Question (MCQ) format for the knowledge assessment. Importantly, statisticians and quantitative research experts were consulted, and as the aim of the knowledge test questions was to assess knowledge gain, rather than to act as a formal assessment tool, no formal statistical analysis was performed to ascertain validity of the testing instrument. Evaluation of validity evidence is important, but beyond the scope of this thesis, and will be reserved for future work. Instead, the focus was upon creating high-quality, concise, and legible questions and corresponding answer options. There is a wealth of resources available that stipulate the qualities of writing high-quality, effective MCQs. For example, the National Board of Medical Examiners (NBME), have published guidelines on creating MCQs that align well with educational goals.[68]

Test Blueprint

Prior to creating the items, a test blueprint was created. Blueprinting is the planning of the test against the learning objectives of a course or competencies essential to a specialty.[69] The learning objectives (see Figure 13-16) and topics were listed and the script was re-analyzed in detail to ensure that the script represented adequate breadth and depth of information. Two to three questions covering each topic specifically were next outlined. Each question was given an appropriate context, which ranged from core knowledge recall (e.g. the anatomical relationship between two structures) to clinical scenarios (e.g. a patient presenting to the Emergency Department with an ailment). Each video and main topic had varying numbers of subtopics, and subsequently the exams corresponding to each video varied between 10-30 questions in length.

Writing the questions and items

Using the test blueprint, 68 MCQs were written. Following extensive review of best practices for question writing, four draft tests were created, with MCQs matching each of the topics/learning objectives identified. Following development of the question stem and options, they were carefully reviewed using the guidelines outlined by NBME. The NBME have outlined 'five basic rules for writing MCQs'.[68] These were adhered to, when writing the question items for this curriculum, and secondary review was performed upon completion to ensure completion, the absence of redundancy and unintentional bias.

In addition, when items had been written, they were reviewed against 15 criteria or common 'flaws' of MCQs, also set by the NBME in their guide.[68] These criteria were made available to subsequent reviewers of the tests, prior to distributing the exam. These principles were adhered to throughout the test creation process. Each question was designed to be scored as either correct (one point) or incorrect (zero points), with no partial credit or negative marking. The complete four pre- and post-test MCQs can be found in Appendix A.

A neurosurgery subject matter expert (WTC) subsequently reviewed the four MCQ-tests. In addition, three colleagues (n=3, senior medical student, attending physician, resident physician) piloted the tests, and were invited to comment on both the difficulty level of the tests (e.g. were they appropriately difficult?), and the language and design of the tests (e.g. are the questions clear?), as well as with the above mentioned criteria, as displayed above.

Self-efficacy survey creation

The needs assessment and literature review also indicated that a self-efficacy survey was desirable, as literature had also shown that self-efficacy was low within neurosurgery, for non-neurosurgical experts and specialists.[52,58] After an extensive literature review, no prior self-efficacy instrument was found that was specifically applicable to neurosurgery. However, previous work had outlined the process of outlining self-efficacy scales, e.g. Robotham and Schmitz (2013) and Dandavino et al. (2013).[70,71] Both these scales used the General Self-Efficacy Scale (GSE) (Schwarzer and Jerusalem, 1995), and modified it according to the learning objectives and goals for the relevant curricula. Using the blueprint for the MCQ knowledge test, questions assessing self-efficacy were developed for each of the main topics.[72] The self-efficacy survey is included in Appendix A. Performing psychometric analyses of the self-efficacy scale (e.g. evaluation of validity evidence) was beyond the scope and time-constraints of this project. However, prior to usage in the study, the self-efficacy survey was piloted in three learners that were representative of the target group, to ensure evidence of test construct.

A Note on Adult Leaners

Many of the principles driving the potential key success factors of asynchronous, video-based learning appear to be interrelated to the principles of adult learning. Malcolm Knowles (1980) described the concept of 'andragogy', to distinguish how adult learners assimilate information, compared to children.[73] Adult learners have a different *modus operandi*, compared to younger learners, in terms of the way they approach and deal with learning, and this must be considered, when developing curricula for adult learners. These principles include that adult learners are more focused on self-directed learning with less dependency on tutors. Accordingly, adults use their own experiences to help learning, and the readiness to learn is often based upon new 'life roles'.[73] In addition, adult learning is centered on problem-solving and practical applicability, and motivation to learn comes from an internal drive, not from external rewards.[74] Consequently, Knowles (1984) has followed up with a number of suggestions on how to leverage the unique characteristics of the adult learner.[75] These include that learning should take place in a cooperative or collaborative climate, that learners' needs must be assessed specifically and closely matched with learning objectives, and – not least important – that the quality of learning materials must be evaluated and iterated continuously.[75] Adult learners need to know the reasons for learning a topic, and the onus to communicate this lies on the instructor.[75] Furthermore, active learning is favored, rather than merely memorization of information or facts. Additionally, the concept of self-directed learning is pivotal in the context of adult learning. Indeed, 70 percent of adult learning is self-directed, and learners take responsibility for their own learning.[75] The benefits to self-directed learning include the fact that it can be easily incorporated into the otherwise busy daily routine that adult learners may have, but it requires specific strategies from the instructor to be effective. These include, for example, self-assessment with clear learning objectives, supplying appropriate learning resources, and giving encouragement and support.[76] However, even though medical students would be classified as adult learners rather than children, studies have shown that medical students, especially in their later years of medical school, may prefer to approach learning in a surface-learning, or result-orientated, manner, rather than the deep approach required for lifelong learning.[77] Clearly, even though the concept of self-directed learning, as deployed through an asynchronous, video-based curriculum, should be well suited to adult learners, it may be unclear whether medical students indeed behave as adult learners in practice. Subsequently, a study evaluating the need and effectiveness of an asynchronous curriculum might also indirectly indicate what type of learners medical students are, through studying the outcome of the curriculum and the compliance.

Study design: An asynchronous, video-based two-week neurosurgery curriculum for clerkship medical students

Following content creation, the study groups were profiled and a study design was developed. The process of achieving these two outcomes involved balancing the 'ideal' study design with what was practically attainable, given the study timeline and context.

Given the research question hypothesis, and practical constraints, the following study design was outlined (see Figure 18 below).

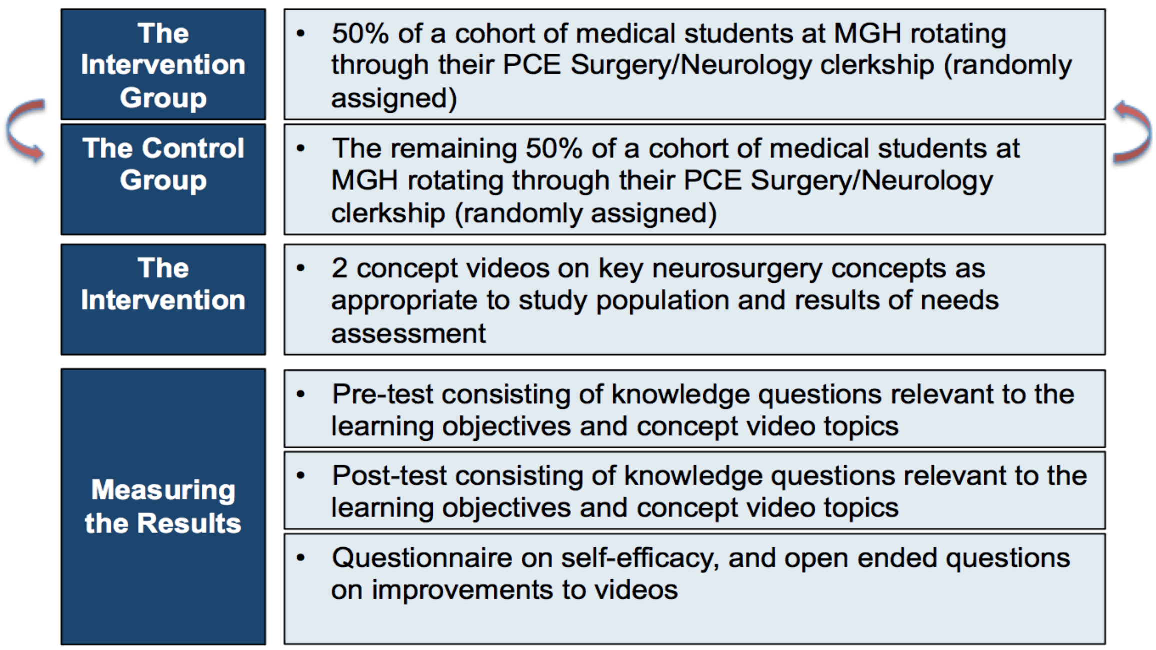


Figure 18. Study Group and Design Summary

Each clerkship received an introductory email (see Appendix C) the day before each planned session. This email outlined the purpose of the study, the voluntary nature of it, and the logistics of the two weeks of the study. The next day, a one-hour face-to-face meeting was scheduled between the students and the study principal investigator (GCA), where 20 minutes were spent to introduce the study and answer any questions. The students were then given the paper-based knowledge and self-efficacy pre-tests and asked to complete them within a 30-minute time period. Once completed, the students remained in the room and further questions were invited.

Each student was randomly assigned to one of two pairs of videos (Intracranial hemorrhage, Hydrocephalus) or (Neuro-Imaging, Glasgow Coma Scale). The following day, the students received an email (See Appendix C) with instructions, and hyperlinks for the Mediasite® account, containing the assigned videos. Five days later, a reminder email (see Appendix C) was sent to the group, reminding them to watch the videos, and as an invitation to any questions.

On day 14 of each study cycle, another one-hour face-to-face session was scheduled between the students and study PI. Students were given 30 minutes to complete the post-test knowledge and self-efficacy tests were administered to each student. Once this period had elapsed, the students were invited to ask further questions and invited to provide any feedback to the process. The logistics of the study are summarized below in Figure 19.

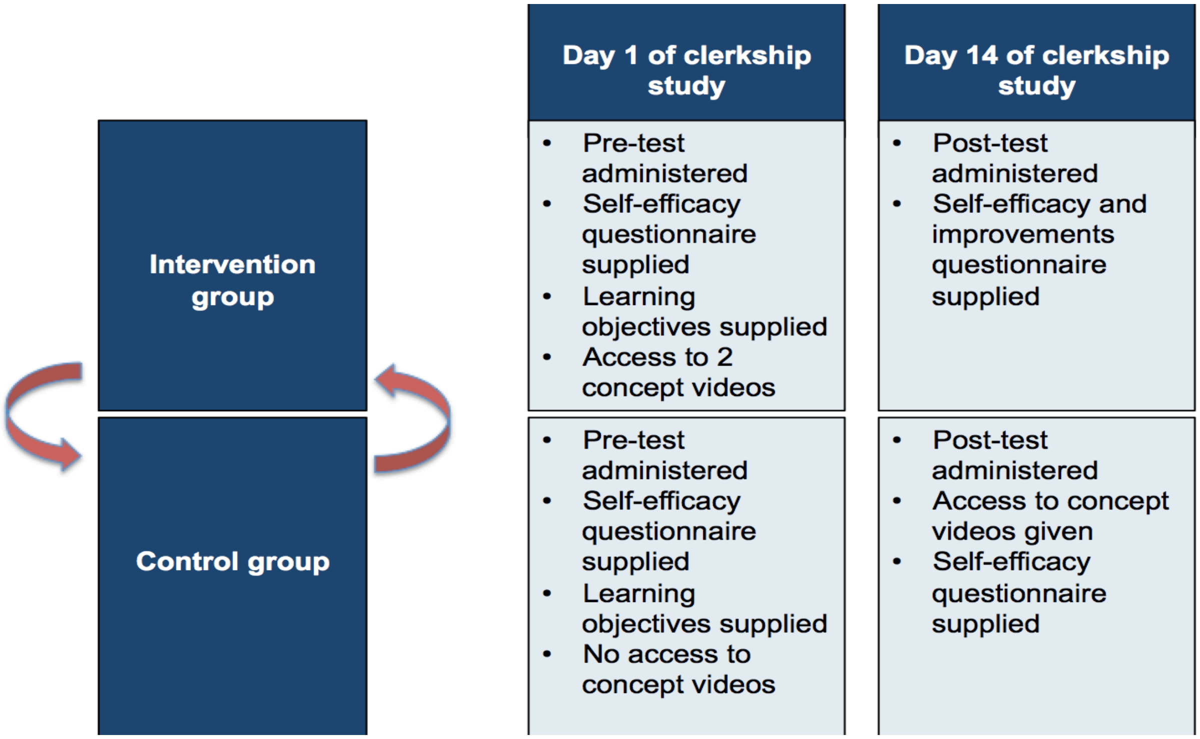


Figure 19. Study design and logistics

Having administered the pre-and post-tests, the papers were stored securely until the completion of the study.

Data Collection and Analysis

Once all the study cycles had been completed, the pre- and post-knowledge tests were scored according to a set-marking scheme (see Appendix A), and self-efficacy scores were entered and summed in Microsoft Excel®. In addition to the knowledge pre- and post-tests, and the self-efficacy pre- and post-tests, the dashboard of Mediasite® was used to download the analytics of video usage, pertaining to views, hotspots of activity, and time accessed. Please see Appendix C for examples of these data.

Using the tabulated data for knowledge scores in Excel, scores for each of the two groups of videos were added to two composite scores. The tabulated data in Excel® was imported into SPSS® (Version 24, Chicago, IL) and statistical analysis relevant to the research hypothesis and questions was performed (see below in Results). A variety of statistical tests (e.g. Paired T-test, Independent T-test, 2- and 3-factor ANOVA, correlation) were used to understand differences between groups. We applied a student paired t-test to compare pre- and post-test summed scores of knowledge and self-efficacy for each group of students, an independent t-test to compare summed scores of knowledge and self-efficacy between each group, as well as ANOVA. Statistical significance was set at ≥ 0.05. Please see more details below in Results.

The Mediasite® Analytics dashboard was used to extract key data (see Appendix C) regarding viewing statistics. The Mediasite® offers a wealth of analytics to understand video usage patterns and activity. Given the time constraints and scope of the study, the dashboard was primarily used to identify students who adhered to the curriculum, and those who did not (i.e. did not watch the videos). This is further discussed below in Results.

2.3 Results

Needs Assessment

The results from the needs assessment have been included in Appendix C. In summary, both investigations reaffirmed the low confidence regarding the diagnosis and management of neurosurgical conditions, in particular for the subject areas studied within this curriculum. Furthermore, both needs assessments conveyed concept videos as a well-received and appreciated medium through which material can be taught, especially within the context of an already hectic and content-filled curriculum.

Main study

The raw data scores for the knowledge and self-efficacy instruments are available upon request.

Knowledge and self-efficacy scores: Compliant students (engaged with curriculum, n=16) versus Non-compliant students (did not engage with curriculum, n=12):

a) Was there a change in knowledge and self-efficacy scores from pre-test to post-test in the group of students who watched the videos, versus those who did not?

- **Yes. Statistically significant improvement in knowledge scores from pre- to post-test for all students who watched videos**
- **Non-compliant students showed no statistically significant improvement in knowledge scores**
- **Overall improvement in self-efficacy scores in both compliant and non-compliant students**

b) Was there a statistically significant difference in the post-test scores (for knowledge and self-efficacy) between students who watched the videos, versus those who did not?

- **Strong statistically significant difference in mean total post-test knowledge scores between compliant and non-compliant students**
- **No statistically significant difference between mean self-efficacy post-test scores of compliant versus non-compliant students**

Knowledge and self-efficacy scores: Content area 1+2 versus Content area 3+4

a) Was there a statistically significant effect of the videos and curriculum on knowledge scores, from pre-test to post-test?

- **Findings suggest a positive (but not statistically significant) incremental improvement in content areas of test related to videos assigned and watched**
- **No statistically significant difference in overall post-test scores between Group 1 and 2**

b) What was the effect of the videos and curriculum on self-efficacy scores, from pre-test to post-test?

- **Strongly suggestive (but not statistically significant) incremental improvement in content areas of test related to videos assigned and watched**

c) What was the incremental effect on knowledge and self-efficacy scores, related to the videos they were given, for the students who engaged in the curriculum?

- **No statistically significant difference in specific post-test scores between Group 1 and 2 for assigned content areas**

Sub-group analysis: Compliant students

<u>**Knowledge**</u>

Table 1. Frequency table of compliant students

	Learning Focus (Content area)	**n**
Group 1	1+2	6
Group 2	3+4	10

As can be seen in Table 1, there were 6 students in the group of compliant students who watched Videos 1 and 2, and there were 10 students in the group of compliant students who watched Videos 3 and 4.

Descriptive statistics were calculated, including the mean scores for pre- and post-knowledge tests. The pre-and post-test knowledge scores, for each of the content areas, have been included in Table 2 below.

Table 2. Descriptive statistics – Mean pre- and post-test knowledge scores of compliant students (Standard Deviation (SD) in brackets)

	Pre-test (1+2)	**Pre-test (3+4)**	**Post-test (1+2)**	**Post-test (3+4)**
Group 1	0.66 *(0.11)*	0.65 *(0.13)*	0.78 *(0.093)*	0.73 *(0.098)*
Group 2	0.67 *(0.078)*	0.64 *(0.13)*	0.76 *(0.099)*	0.80 *(0.13)*

Pre-test scores

In Table 2, it can be noted that the mean pre-test knowledge score on Learning Focus 1 and 2 (corresponding to the material in Videos 1 and 2), was 0.66 for the group who had been assigned Videos 1 and 2 (n=6), and 0.67 for the group who had been assigned videos 3 and 4 (n=10). The pre-test knowledge scores on Learning Focus 3 and 4 (corresponding to Videos 3 and 4), was 0.65 for the group who had been assigned to Videos 1 and 2, and 0.64 for the groups who had been assigned to Videos 3 and 4.

Post-test scores

In Table 2, it can be noted that the mean post-test knowledge score on Learning Focus 1 and 2 (corresponding to the material in Videos 1 and 2), was 0.78 (+ 0.12) for the group who had been assigned Videos 1 and 2 (n=6), and 0.76 (+ 0.09) for the group who had been assigned videos 3 and 4 (n=10). The post-test knowledge scores on Learning Focus 3 and 4 (corresponding to Videos 3 and 4), was 0.73 (+0.08) for the group who had been assigned to Videos 1 and 2, and 0.80 (+0.16) for the groups who had been assigned to Videos 3 and 4. Having calculated the mean pre- and post-test scores, ANOVA analysis (repeated measures) was used to compare the groups and knowledge scores, and to test the following sub-hypothesis regarding how students performed in the post-test versus pre-test, and how these scores might vary between the different content areas of the exam:

- The students in Group 1 (assigned videos 1 and 2) would score differentially higher in content areas 1 and 2 of the post-test, compared to Group 2.
- The students in Group 2 (assigned videos 3 and 4) would score differentially higher in content areas of 3 and 4 of the post-test, compared to Group 1.

Pre-test versus Post-test knowledge scores irrespective of learning focus

An improvement in overall post-test scores for all students who had engaged with the curriculum was explored (i.e. improvement over time). The compliant students (i.e. watched videos), had a marked and significant improvement in their knowledge scores from pre- to post-test in all content areas of the post-test exams, irrespective of learning focus of videos watched ($F=27.1$, $df=1.1$, $p<0.001$).

Incremental Pre-test versus Post-test knowledge scores considering learning focus

A differential improvement in the content areas for which students had been assigned videos was explored (Time x Content x Focus). There appeared to be a strong tendency for students to perform better in the post-test exam content areas relating to the videos they had been assigned. This has been displayed in Figures 20 and 21.

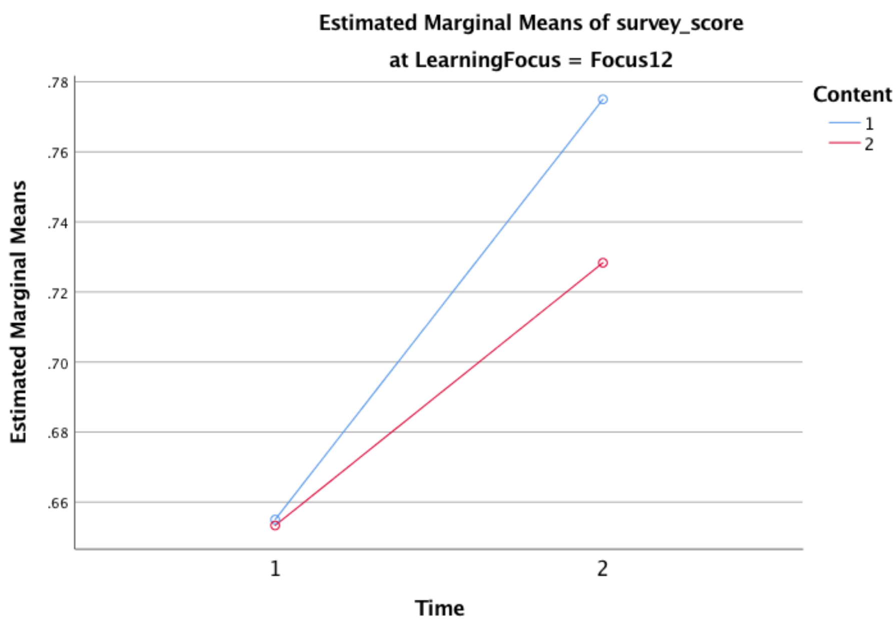


Figure 20. Incremental knowledge score improvement of Group 1 (blue line) versus Group 2 (red line) in Content areas 1 and 2.

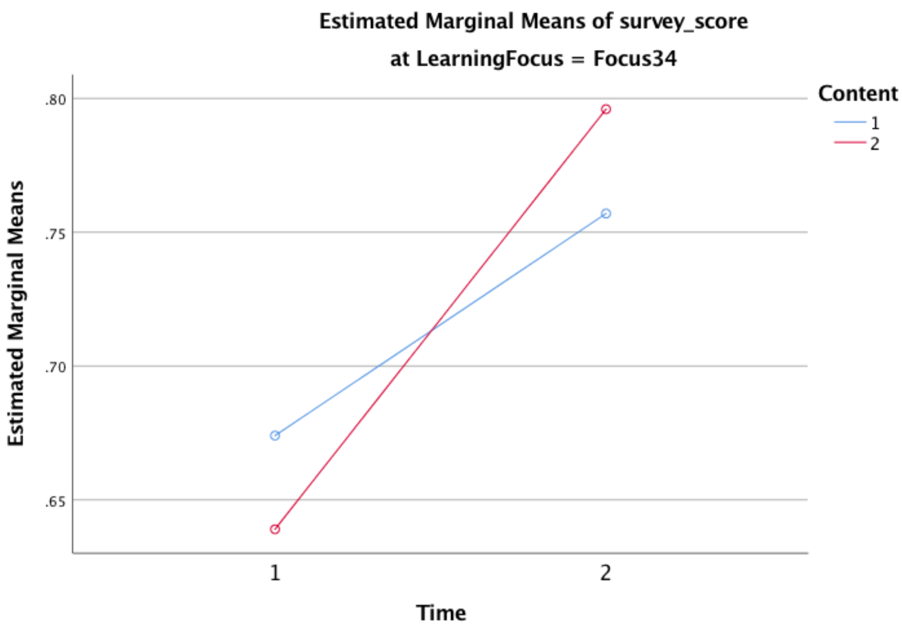


Figure 21. Incremental knowledge score improvement of Group 1 (blue line) versus Group 2 (red line) in Content areas 3 and 4

As can be seen in Figure 20 and 21, both groups scored higher overall on the post-test, and appeared to score preferentially higher in the content areas corresponding to the videos they had been given. However, despite this strong trend, it was not statistically significant (F=4.25, df=1.1, p = 0.058). The potential reasons for this will be discussed below in Discussion. NOTE. The study appeared to be underpowered for this portion of the analysis (power = 0.484).

Post-test knowledge scores considering learning focus

We wanted to determine whether Group 1 scored preferentially higher in content areas 1 and 2 (corresponding to videos watched) than Group 2. Conversely, we wanted to determine whether Group 2 scored significantly higher in content areas 3 and 4 (corresponding to videos watched), than Group 1. It was found that, although the <u>incremental</u> improvement (as above) appeared to be related to the topics for which the group has watched videos (albeit not statistically significant), no significant difference was found between the two Groups and the post-test scores corresponding to their assigned subject areas ($F=0.31$, $df=1.26$, $p=0.59$, power = 0.08).

<u>Summary of Knowledge Results for Compliant Students:</u>

- **Statistically significant improvement in knowledge scores from pre- to post-test for all students who watched videos**
- **Strongly suggestive (but not statistically significant) incremental improvement in content areas of test related to videos assigned and watched**
- **No statistically significant difference in overall post-test scores between Group 1 and 2**
- **No statistically significant difference in specific post-test scores between Group 1 and 2 for assigned content are seen**

<u>Self-efficacy</u>

The 3-factor repeated measures ANOVA analysis was performed for self-efficacy. Mean pre- and post-test self-efficacy scores of compliant students are displayed below in Table 3.

Table 3. Mean pre- and post-test self-efficacy scores of compliant students (Standard Deviation (SD) in brackets)

	Pre-test (1+2)	**Pre-test (3+4)**	**Post-test (1+2)**	**Post-test (3+4)**
Group 1	4.3 *(1.8)*	4.7 *(2.1)*	7.7 *(1.0)*	6.0 *(2.3)*
Group 2	4.7 *(2.8)*	5.3 *(1.3)*	6.2 *(1.6)*	6.7 *(1.4)*

Pre-test scores

In Table 3, it can be noted that the mean pre-test self-efficacy score on Learning Focus 1 and 2 (corresponding to the material in Videos 1 and 2), was 4.3 for the group who had been assigned Videos 1 and 2 (n=6), and 4.7 for the group who had been assigned videos 3 and 4 (n=9). The mean pre-test self-efficacy score on Learning Focus 3 and 4 (corresponding to Videos 3 and 4), was 4.7 for the group who had been assigned to Videos 1 and 2, and 5.3 for the group who had been assigned to Videos 3 and 4.

Post-test scores

In Table 3, it can be noted that the mean post-test self-efficacy score on Learning Focus 1 and 2 (corresponding to the material in Videos 1 and 2), was 7.7 (+ 3.4) for the group who had been assigned Videos 1 and 2 (n=6), and 6.2 (1.5) for the group who had been assigned videos 3 and 4 (n=9). The post-test self-efficacy scores on Learning Focus 3 and 4 (corresponding to Videos 3 and 4), was 6.0 (+1.3) for the group who had been assigned to Videos 1 and 2, and 6.7 (+1.4) for the groups who had been assigned to Videos 3 and 4.

Having summarized the mean pre- and post-test scores, ANOVA analyses (2- and 3-factor, repeated measures) were performed to explore how students scored in self-efficacy in the post-test versus pre-test, and how these scores might have varied depending on which videos they had been assigned.

Pre-test versus Post-test self-efficacy scores irrespective of learning focus

The post-test self-efficacy score was found to be significantly higher than pre-test self-efficacy score for both Group 1 and Group 2, irrespective of learning focus (F=5.07, df=1.13, p=0.04).

This has been illustrated in Figure 22.

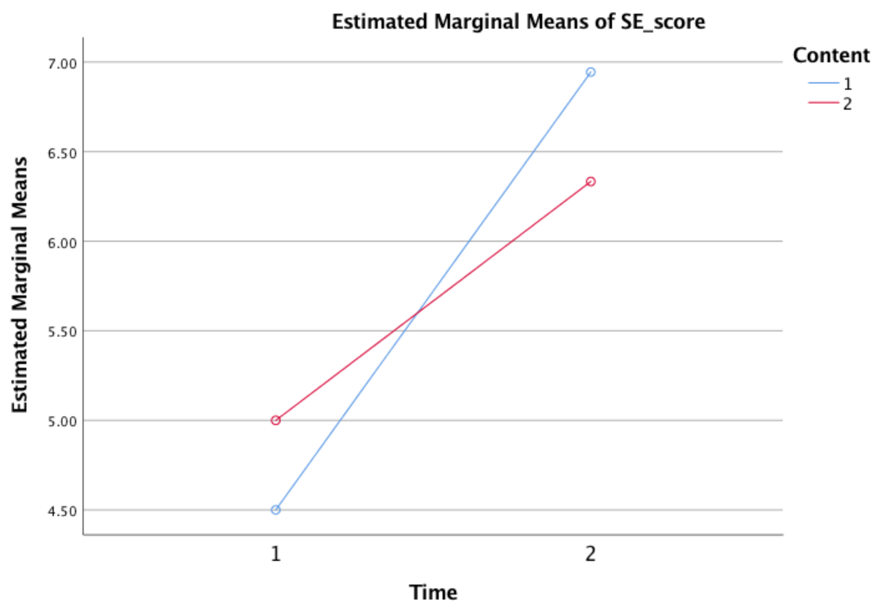


Figure 22. Mean pre- and post-test self-efficacy scores of Group 1 (blue line) and Group 2 (red line)

Incremental Pre-test versus Post-test self-efficacy scores considering learning focus

Using SPSS, a 3-factor repeated measure ANOVA analysis, a differential improvement in the self-efficacy score, corresponding to the content areas for which students had been assigned videos, was explored. (Time x Content x Focus). There appeared to be a strong tendency for students to perform better in the post-test exam content areas relating to the videos they had been assigned.

This has been displayed in Figures 23 and Figure 24, below.

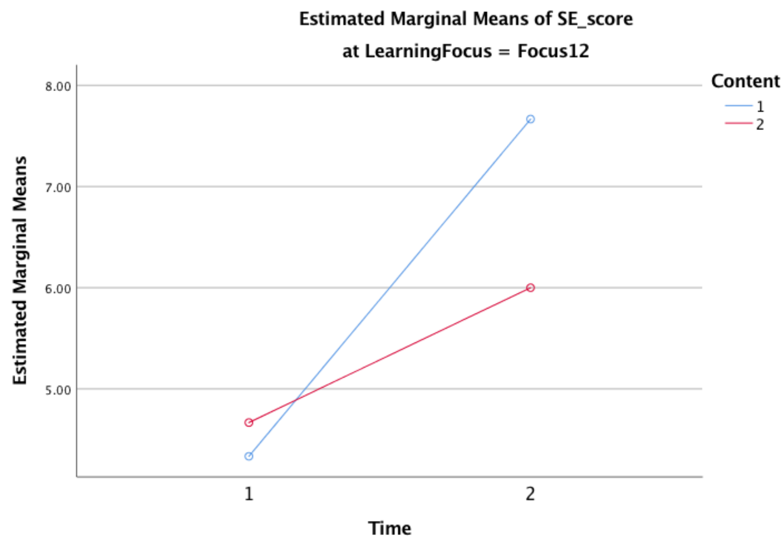


Figure 23. Incremental self-efficacy score improvement of Group 1 (blue line) versus Group 2 (red line) in Content areas 1 and 2

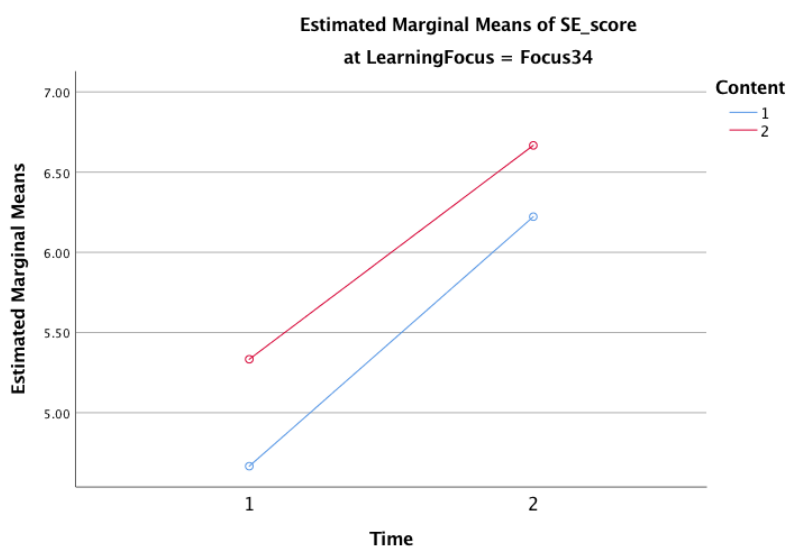


Figure 24. Incremental self-efficacy score improvement of Group 1 (blue line) versus Group 2 (red line) in Content areas 3 and 4

As can be seen in Figures 23 and 24, both groups scored higher overall on the post-test, and appeared to score preferentially higher in the content areas corresponding to the videos they had been given. However, despite this strong trend, it was not statistically significant at a level of $p < 0.05$ (F=3.25, df=1.13, p = 0.09). The potential reasons for this will be discussed below in Discussion. **Note.** The study appeared to be underpowered for this portion of the analysis (power = 0.386).

<u>Summary of Self-efficacy Results for Compliant Students:</u>

- **Statistically significant improvement in self-efficacy scores from pre- to post-test, for all students who watched videos**
- **Strongly suggestive (but not statistically significant) incremental improvement in content areas of test related to videos assigned and watched**
- **No statistically significant difference in specific post-test scores between Group 1 and 2 for assigned content areas**

Comparing compliant students (overall) to non-compliant students

As noted above, the compliant students improved both knowledge and self-efficacy scores statistically significantly. In order to compare whether any such trend was seen in the non-compliant (i.e. did not watch videos) group of students, a paired T-test was performed to check for similar trends as seen above. The key data are summarized below in Table 4.

Table 4. Knowledge (**K**) and self-efficacy (**SE**), pre- and post-test scores: Non-compliant students (Standard Deviation (SD) in brackets)

		Mean score
Content area 1	**PreK12**	0.61 *(0.03)*
	PostK12	0.63 *(0.02)*
Content area 2	**PreK34**	0.57 *(0.02)*
	PostK34	0.53 *(0.02)*
Content area 1	**PreSE12**	4.33 *(0.05)*
	PostSE12	5.92 *(0.36)*
Content area 2	**PreSE34**	4.83 *(0.49)*
	PostSE34	6.08 *(0.43)*

As can be seen above, Group 1 of the non-compliant students had a mean pre-test knowledge score of 0.61, and a subsequent mean post-test score of 0.63.

Group 2 had a mean pre-test knowledge score of 0.57, and a subsequent mean post-test knowledge score of 0.53. Furthermore, Group 1 of the non-compliant students had a mean pre-test self-efficacy score of 4.3 in their assigned content area 1+2, and a subsequent mean post-test score of 6.0. Group 2 had a mean pre-test self-efficacy score of 4.8 in their assigned content area 3+4, and a subsequent mean post-test score of 6.1. The paired sample correlations are summarized below in Table 5.

Table 5. Paired Samples correlations – Non-compliant students

		N	Correlation	P
Pair 1	**PreK12 & PostK12**	12	.41	.18
Pair 2	**PreK34 & Post34**	12	-.36	.25
Pair 3	**PreSE12 & PostSE12**	12	.61	.04
Pair 4	**PreSE34 & PostSE34**	12	.22	.49

As can be seen from Table 5, no significant difference was found in terms of knowledge scores, between pre- and post-test, in the non-compliant group of students. Interestingly, in terms of self-efficacy, a statistically significant increase was seen in Group 1 in their assigned content areas, despite not engaging with the video material. No such difference was seen in Group 2. This was confirmed by a paired student t-test (see below, Table 6).

Table 6. Paired Samples T-test – Non-compliant students

	Mean	t	df	Sign. (2-tailed)
PreK12 - PostK12	-.026	-.955	11	.36
PreK34 - Post34	.036	.822	11	.43
PreSE12 - PostSE12	-1.58	-3.978	11	.002
PreSE34 - PostSE34	-1.25	-2.159	11	.05

Finally, in order to compare the non-compliant students with the compliant students, in terms of knowledge and self-efficacy, an independent samples t-test was performed for post-test knowledge and self-efficacy scores. The key data and group statistics are summarized below in Table 7.

Table 7. Mean total post-test scores (knowledge (K) and self-efficacy (SE)) of compliant vs. non-compliant students

	Student Group	**n**	**Mean total post-test score**
K	**Compliant**	16	1.53
	Non-Compliant	12	1.17
SE	**Compliant**	15	13.20
	Non-Compliant	12	12.00

Knowledge: Post-test scores of compliant versus non-compliant students

A statistically significant difference between the mean total post-test knowledge scores of the compliant and non-compliant students was seen ($F=3.53$, $df=26$, $p<0.001$. This implies that the students who engaged with the curriculum (i.e. watched the videos), scored significantly better in the post-test knowledge test.

Self-efficacy: Post-test scores of compliant versus non-compliant students

Interestingly, no statistically significant difference in mean total post-test self-efficacy scores was seen when comparing compliant and non-compliant students. This implies that self-efficacy increased with this intervention, whether or not students had watched the videos or not.

<u>Summary of Compliant versus Non-compliant students</u>

- **Non-compliant students showed no statistically significant improvement in mean summed post-test knowledge scores**
- **Statistically significant difference in mean total post-test knowledge scores between compliant and non-compliant students**
- **No statistically significant difference in mean summed post-test self-efficacy scores between compliant and non-compliant students**

A note on video-analytics results

For the purpose of this study, Mediasite® was primarily used to monitor student compliance to this study. The key video analytics data have been included in Appendix C, and will be analyzed in subsequent studies.

2.4 Brief Discussion

The sheer volume of content that must be learned in current medical school curricula is immense. From the pre-clinical years to the final clinical sub-internships, medical students have to develop a basic understanding for a wide variety of topics, as well as acquire many skills. For most students, medical school is followed by residency, which leads to training in a particular specialty. However, physicians must have some basic knowledge beyond their own specialty. As a neurosurgical trainee, one must still be able to interpret an EKG, analyze a radiograph of the chest, and perform a clinically appropriate examination of the abdomen, in someone with suspected appendicitis. Similarly, one would expect a primary care physician to be able to distinguish between an epidural and subdural hemorrhage clinically and on a CT scan, or measure a patient's level of consciousness. Missed diagnoses and delayed treatments are especially problematic in subarachnoid hemorrhage, and many other neurosurgical conditions.

Yet, worryingly, the literature is clear that the basics of neurosurgery are currently under-delivered in virtually all medicals schools in the United States. Furthermore, the weight that is placed upon neurosurgery topic questions in current summative examinations (e.g. USMLEs), is simply not representative of the burden of neurosurgical pathology that is encountered in today's clinical practice. In this study, I aimed to develop a focused, asynchronous, video-based, curriculum that could be deployed within a short time span, and have significant effects and lasting impact on student learning.

The results from the needs assessment supported the importance of this study. Both medical students, and qualified hospitalist physicians, unanimously considered themselves relatively unsure of how to deal with basic neurosurgical conditions. Yet at the same time, there was an obvious desire to change this status quo. Furthermore, the idea of being taught in an asynchronous manner through videos was generally positively received by both groups, given their own previous experience with videos as part of their education.

Subsequently, following the needs assessment, the curriculum was developed and deployed within two clerkships. A pre- and post-knowledge test was performed for each cohort of the curricula, along with a pre- and post- self-efficacy questionnaire. The results from these two measures expanded upon some of the previous literature on the subject, but within the new context of neurosurgery. Furthermore, significant insights pertinent to the delivery of a curriculum in general were gathered, that were beyond the scope of this study, and indeed the research question and hypothesis, but are worthy a significant mention. Specifically, this study showed that a focused neurosurgical curriculum composed of videos and learning objectives can have a significant and measurable benefit on knowledge acquisition, for those students who choose to comply and engage with the curriculum. Whilst the students who did not engage with the curriculum failed to improve their scores from pre-test to post-test, those who did engage with the videos improved significantly. Interestingly, this improvement was not specifically limited to the videos the students received. Instead, the students improved across all four topic areas for which they were given learning objectives for. There may be a multitude of reasons for this, including both student and curriculum factors.

In terms of student factors, the students who chose to engage with the curriculum may have been more motivated to learn neurosurgery even before the study commenced, which would create a propensity for them to also watch the videos more diligently, and thus score better in the knowledge tests. Furthermore, the students who engaged with the curriculum may simply have had more time at their disposal to engage with the curriculum. In further studies, the reasons for engagement and non-engagement should certainly be explored.

The curriculum itself may have had a motivating effect on students. If the videos they were assigned were of subjectively good didactic quality, then it is possible that these created an interest to read up on the additional topics, for which the students were not assigned videos. Again, this will be explored in further follow-up work.

In terms of self-efficacy, the trends seen were rather more enigmatic. Interestingly, all students' self-efficacy scores improved following the intervention, irrespective of whether they had engaged in the curriculum or not. As with the trends seen with knowledge scores, there may be multiple reasons for this, including a disconnect between one's perceived, versus one's objectively, measured ability. Indeed, whilst self-efficacy improvement in isolation may be misinterpreted as a positive finding, it was the intention and hypothesis of this study that self-efficacy improvement would follow rather closely with knowledge improvement. Whilst it is beneficial for students and physicians to be confident in their ability to diagnose and treat neurosurgical conditions, it is also ominous that self-efficacy would improve without knowledge improvement. Whilst further study will be performed to further evaluate these findings, and improve the statistical power of this analysis, this may be a significant finding that further stresses the need for ensuring that we do indeed teach and examine the necessary knowledge.

Learning analytics revealed that the study compliance was not low, and many students chose not to engage with the video-content, in between pre- and post-tests. The potential reasons for this are multiple. Firstly, the curriculum was voluntary, and there were no negative, formal implications for choosing to take part or not. Secondly, within one major clerkship, the scheduling of the study fell very closely to summative exams; so many students are likely to have chosen to prioritize these, instead of the voluntary neurosurgery curriculum. Thirdly, it is possible that the status quo seen amongst medical school deans regarding the unnecessary nature of neurosurgery to be taught in medical school has disseminated to the student-level. This highlights an important point. Anecdotally, it appears that medical students are extraordinarily strategic learners, previous studies have shown that medical students have a propensity to focus on learning material that is examined in a summative manner. This is understandable, given the sheer volume of content that is taught in medical school. However, it also raises the point of how we ensure that students commit to the ethos of learning for life (or their career), rather than learning for their most imminent exams. In fact, it further reinforces the point that if we see it as crucial for students to know certain topics, of which hydrocephalus, intracranial hemorrhage, neuro-imaging, and the Glasgow Coma Scale clearly are some, then they should also be examined in a summative manner. The implication of the strategic learner nature of the students and its potential contrast with the ethos of lifelong learning was potentially obvious in this study: students chose not to engage, simply because the curriculum was voluntary, and did not count toward any final grade. However, it reinforces the argument made by many authors, including myself, that neurosurgery must have a larger, formal role within the medical school curriculum.[52]

Neurosurgery is a fascinating and challenging specialty, and the ability to become an accomplished physician within, requires many years of training, just as with any other of the many specialties. However, there are core topics that we must be competent to understand as physicians from all these specialties, and as shown in literature and this study, neurosurgery knowledge is falling behind at the medical school level.[52,53,54,55,56]

Given the complexities and practical constraints of teaching in the hectic, time-pressured neurosurgical environment, the asynchronous video-based curriculum demonstrated in this study is promising. In addition to having significant impact on knowledge, and on self-efficacy (albeit also in those who did not engage with the curriculum), the practical nature of it may fit very well into the neurosurgical environment, in view of the limited resources and time available and dedicated to teaching medical students. Furthermore, as literature suggests, it is likely that a blended learning approach, where this curriculum is combined with face-to-face teaching and other activities (e.g. simulation), may have an even more significant effect.[16,48]

To change the mindset of medical schools and examination boards, regarding the need to learn neurosurgery, is currently an ongoing process. However, this study demonstrates that a focused, video-based curriculum can be an effective tool to increase knowledge and self-efficacy amongst learners for a topic, as well as possibly have some significant effects upon motivation. Further study on the subject will aim to confirm these conclusions, as well as explore other strategies for implementing the curriculum. However, clearly, a blended learning approach, including the use of concept videos, may be a very promising and viable option, to remedy the current demonstrated shortfall of neurosurgical teaching that has been observed in medical education. Future studies will aim to expand upon the conclusions from this study, improve learner compliance, and analyze learner analytics in further depth. Given the current situation in neurosurgery, along with a challenging neurosurgical learning environment, this curriculum represents a viable and cost-effective opportunity to create a national neurosurgery curriculum for medical students, expanding upon the work by the Congress of Neurological Surgeons, and addressing the current knowledge and self-efficacy gap for diagnosing, managing and treating neurosurgical pathology.

Chapter 3: Discussion and Perspectives

3.1 Limitations

This study was designed to minimize limitations and maximize its scientific rigor, given the various constraints placed upon it. However, there were several limitations that were predicted prior to the study, and more encountered as the study progressed.

Study group

There were several limitations with regards to the study groups involved, from the needs assessment stage to the final stages of the main study.

For the needs assessment, the intention was to pick groups that were representative of the main study group. Whilst this was achieved to some extent, given time constraints, convenience sampling had to be used. The survey sent to the hospitalists had a relatively low response rate, as it was voluntary, and only sent out once. It is therefore possible that the physicians who responded were positively biased toward the topic at hand, and thus, any conclusions drawn from the needs assessment may have been biased. Furthermore, the discussion groups used for the needs assessment were composed of students from the HMS Surgical student society. This may possibly create bias within the needs assessment as these students have an increased interest in surgery in general.

In terms of the main study group, two clerkships were chosen: the PCE surgery clerkship and neurology clerkship, and a number of cohorts within these clerkships were used in the study. Whilst these groups were the intended target audience, the study would have ideally examined a wider range of students in different clerkships to improve the generalizability of the study. Also, the timing of this study within some of these clerkships was not ideal. In one of the clerkships, this curriculum was scheduled close to the shelf exams, and subsequently the compliance rate of watching the videos was comparatively low. Furthermore, some students (n=4) ended up rotating directly from one of the clerkships in the study to the other (e.g. from PCE surgery to neurology) and thus had to be excluded from the study. Unfortunately, some students completed the pre-test, but were not present for the post-test (n=5) and had to be excluded from the study.

Intervention

The intervention (i.e. curriculum) was produced with the utmost care for educational quality. However, given the economic and financial constraints of the study, some limitations were present. Although there was a review process in place for the entire curriculum, from developing the learning objectives and pre- and post-tests, to writing the scripts, and to producing the videos, most of this work was created by the primary author. While every attempt was made to ensure relevance and quality of the curriculum and educational materials, it is possible that this may have created bias towards which material to include, the style of the videos, and which parts of the material were examined. Ideally, this curriculum would have been created by a group of individuals to ensure balance, and subsequently reviewed by a curriculum committee, to ensure that all potential views are represented. Due to the nature of this thesis, this was not possible.

Instruments of measurement

For this thesis, several instruments to measure, e.g. knowledge and self-efficacy, were created de novo. Whilst they were created with the best attempts to ensure rigor and practicality, with additional review by senior colleagues, no formal statistical testing was done to evaluate validity evidence. Whilst this was acceptable for this pilot study, such formal statistical analysis should ideally be carried out in the future, as the study develops, and certainly if a formal, neurosurgical undergraduate medical school curriculum is created. Furthermore, for this study, the same knowledge test was used for both the pre- and post-knowledge test, although no answer key was provided between these two testing occasions. Statistical analysis comparing students who watched the videos with those who did not, indicated that this is unlikely to have caused any confounders in the study (e.g. students remembering the answers for the questions). However, it is possible that this might be an issue in a different study population, or if the study is carried out on a larger scale.

Statistical Power

Although some of the components of this study were statistically well powered, some of the analyses performed were underpowered, and may have failed to show statistical significance because of this. In several of the analyses, positive trends were seen, but no statistical significance was found. The reasons for the underpowered nature for this study include the potential of the intervention indeed not being effective, the knowledge/self-efficacy tests not discriminatory enough, or most likely, a study population not big enough. The unexpected drop in compliance of video watching compounded the low power in the analyses. In further studies, efforts should be made to improve compliance with the study, and recruit a larger study group.

Learner motivation

As stipulated by the HMS Academy review process, it was made explicitly clear that this study was completely voluntary in nature. Whilst every effort was made to motivate students to prepare, the low compliance rate of the study suggested that some of those efforts failed. As mentioned previously, this is a very likely result of students not being formally examined on the topics given as part of this curriculum. Furthermore, given the hectic nature of some of these students' schedules, priorities must be made, and it is likely that with imminent shelf-exams, a voluntary study would be rather low priority for many of the students.

3.2. Future Research

As part of planning for future research, some positive aspects of the study will be expanded upon, and some of the limited aspects will be reformed. Furthermore, this study focused on the knowledge and self-efficacy gains of students going through the curriculum. The learning analytics data was only minimally explored due to study and time constraints. More analyses of the learning analytics of student experience in this curriculum could be explored. Also, future research should include a larger number of clerkships within and beyond the Harvard Medical School network to increase the variety of students, and the generalizability of the study. The timing of the study could also be improved to ensure that the study is not scheduled too closely to summative exams. As this study expands, so may also the curriculum, with more topics added. When this is done, a formal curriculum review process should be put in place, to ensure educational quality and appropriateness of the material taught and examined. As part of this process, a more extensive student feedback mechanism should be in place reciprocally: i.e. students should be given feedback on their performance, and students should be offered the opportunity to formally give feedback on the curriculum and associated materials. In terms of motivation, this study indicated that the students who complied with watching the videos were motivated to improve their learning of the curriculum beyond the videos that they were assigned. Ideally, the basics of neurosurgery will become a summative component of medical school curricula, and subsequently motivation also positively increased. However, in lieu of this, as this study develops, further efforts will be made to stress the importance to students of these topics, as well as to include more engaging face-to-face sessions, with personalized feedback to each student.

3.3 Concluding Remarks

This study generated several scholarly contributions to the subject of asynchronous, video-based learning, particularly within the context of neurosurgery education in undergraduate medical education. Students who engaged with the curriculum significantly improved their knowledge test scores in all four content areas examined. The students who did not engage with the curriculum did not improve their scores from pre- to post-test. Interestingly, all students who enrolled in the study significantly improved their content-related self-efficacy. This study demonstrates that a focused, asynchronous, video-based curriculum in neurosurgery has a significantly positive effect on knowledge, but not self-efficacy scores (albeit, not significantly differently between compliant and non-compliant students) amongst undergraduate medical students. This represents an exciting prospect to improve the 'status quo' as described amongst medical students with regards to neurosurgical knowledge, and warrants significant further study and development.

4. Bibliography

1. Whitehouse KJ, Moore AJ (2015). Undergraduate teaching of neurosurgery - what is the current practice in the UK and is there a need for improvement? *British Journal of Neurosurgery*: 29(6):753-7. Retrieved online from: https://www.ncbi.nlm.nih.gov/pubmed/26083138

2. Skarparis Y, Findlay CA, Demetriades AK (2016). The teaching of neurosurgery in UK medical schools: a message from British medical students. *Acta Neurochirugica*: 158(1): 27-34. Retrieved online from: https://www.ncbi.nlm.nih.gov/pubmed/26611686

3. Fox B, Amhaz HH, Patel NJ, Fulkerson DH, Suki D, Jea A, Sawaya RE (2011). Neurosurgical rotations or clerkships in US medical schools. *Journal of Neurosurgery*: 114(1): 27-33. Retrieved online from: http://thejns.org/doi/abs/10.3171/2010.5.JNS10245

4. Lobel DA, Kahn M, Rosen CL, Pilitsis JG (2015). Medical student education in neurosurgery: optional or essential? *Teaching and Learning in Medicine*. 27(2): 201-204.

5. Hrastinski (2008). Asynchronous and Synchronous E-Learning. *Educause Review*. (31:4). Retrieved online from: https://er.educause.edu/articles/2008/11/asynchronous-and-synchronous-elearning

6. Yousef AMF, Chatti AM, Schroeder U (2014). The State of Video-Based Learning: A Review and Future Perspectives. *International Journal on Advances in Life Science*. 6(3,4). Retrieved online from: www.iariajournals.org/life_sciences

7. Hurtubise, L, Martin B, Gilliland A, Mahan J (2013). To Play or Not To Play: Leveraging Video in Medical Education. *Journal of Graduate Medical Education* 3: 13-18.

8. Dwyer FM. Strategies for Improving Visual Learning (1978). State College, PA: Learning Services (1–20).

9. Lee JC, Boyd R, Stuart P (2007). Randomized controlled trial of an instructional DVD for clinical skills teaching. *Emerg Med Austral*. 19:241–245.

10. Merkt M, Weigand S, Heier A, Schwan S (2011). Learning with videos vs. learning with print: The role of interactive features. *Learning and Instructi*on. 21: 687-704.

11. Colasante M (2011). Using video annotation to reflect on and evaluate physical education pre-service teaching practice. *Australasian Journal of Educational Technology*. 27(1): 66-88.

12. Sherin MG, Es van EA (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education.* 60(1): 20-37.

13. Zhang D, Zhou R, Briggs O, Nunamaker Jr JF (2006). Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. *Information and Management.* 43: 15-27.

14. Calandra B, Brantley-Dias L, Dias M (2006). Using digital video for professional development in urban schools: A preservice teacher's experience with reflection. *Journal of Computing in Teacher Education*. 22(4): 137.

15. Snelson C, Rice K, Wyzard C (2012). Research priorties for Youtube and video-sharing technologies: A Delphi study. *British Journal of Educational Technology*. 43(1): 119-129.

16. McCarthy J (2010). Blended learning environments: Using social networking sites to enhance the first year experience. *Australasian Journal of Educational Technology*. 26(6): 729-740.

17. Kay R, Edward J (2012). Examining the Use of Worked Example Video Podcasts in Middle School Mathematics Classrooms: A Formative Analysis. *Canadian Journal of Learning and Technology.* 38(2)

18. Balshev T, de Grave WS, Muijtjens AMM, Scherpbier AJJ (2005). Comparison of text and video case in a postgraduate problem-based learning format. *Medical Education*. 39(11): 1086-1092.

19. Lin CC, Tseng YF (2012). Videos and animations for vocabulary learning: a student on difficult words. *Turkish Online Journal of Educational Technology*. 11(4): 346-355.

20. Hsu CK, Hwang GJ, Chang YT, Chang CK (2013). Effects of Video Caption Models on English Listening Comprehension and Vocabulary Acquisition Using Handheld Devices. *Educational Technology & Society*. 16(1): 403-414.

21. Donkor F (2010). The Comparative Instructional Effectiveness of Print-Based and Video-Based Instructional Materials for Teaching Practical Skills at a Distance. *International Review of Research in Open and Distance Learning*. 11(1).

22. Comeaux KR (2005). Cognitive Memory Effects on Non-Linear Video-Based Learning. *Lousiana State University*. Master's Thesis.

23. Lindgren R, Pea R, Lewis S, Rosen J (2007). Learning from digital video: An exploration of how interactions affect outcome. *CSCL*: 447-449.

24. Giannakos M, Chorianopoulos K, Ronchetti M, Szegedia P, Teasley S. Video-Based Learning and Open Online Courses. *International Journal of Emerging Technologies in Learning (iJET)*. 9(1): 4-7.

25. Rich PJ, Hannafin M (2009). Video Annotation Tools Technologies to Scaffold, Structure, and Transform Teacher Reflection'. *Journal of Teacher Education*. 60(1): 52-67.

26. Amini R, Adhikari S, Fiorello A (2014). Ultrasound competency assessment in emergency medicine residency programs. Academic Emergency Medicine. 21(7): 799-801.

27. Ozer MA, Govsa F, Bati AH (2017). Web-based teaching video packages on anatomical education. *Surgical and Radiologic Anatomy*. 39: 1253-1261.

28. Seneviratne U, Ding C, Bower S, Craig S, Leech M, Phan TG (2014). Video-based training improves the accuracy of seizure diagnosis. *Journal of Neurology, Neurosurgery and Psychiatry*. 0: 1-15.

29. Drummond D, Arnaud C, Thouvenin G, Guedj R, Grimpel E, Duguet A, de Suremain N, Petit A (2016). An innovative pedagogic course combining video and simulation to teach medical students about pediatric cardiopulmonary arrest: a prospective controlled study. *European Journal of Pediatrics*. 175: 767-774.

30. Klein MD, Alcamo, AM, Beck AF, O'Toole JK, McLinden D, Henize A, Kahn, RS (2013). Can a Video Curriculum on the Social Determinants of Health Affect Residents' Practice and Families' Perceptions of Care. *Academic Pediatrics*. 14(2): 159-166.

31. Hansen M, Oosthuizen G, Windsor J, Doherty I, Greig S, McHardy K, McCann L (2011). Enhancement of Medical Interns' Levels of Clinical Skills Competence and

Self-Confidence Levels via Video iPods: Pilot Randomized Controlled Trial. *Journal of Medical Internet Research*. 13(1).

32. Ramachandran K, Vijayaraghavan V (2017). Video-based Clinical Anatomy Lectures for First Year Medical Students: A Novel Approach. *International Journal of Scientific Study*. 5(3): 290-293.

33. Rowse PG, Ruparel RK, Brahmbhatt RD, Benzon MD, AlJamal YN, Abdelsattar J, Farley DR (2014). Assimilating endocrine anatomy through simulation: a pre-emptive strike! *The American Journal of Surgery.* 209: 542-546.

34. Rowse PG, Ruparel RK, AlJamal YN, Abdelsattar JM, Heller SF, Farley DR (2014). Catering to Millennial Learners: Assessing and Improving Fine-Needle Aspiration Performance. *Journal of Surgical Education*. 71(6): 54-58.

35. Mishra K, Mathai M, Della Rocca RC, Reddy HS (2017). Improving Resident Performance in Oculoplastic Surgery: A New Curriculum Using Surgical Wet Laboratory Videos. *Journal of Surgical Education*. 74(5): 837-842.

36. Buch SV, Treschow FP, Svendsen JB, Worm BS (2014). Video- or text-based e-learning when teaching clinical procedures? A randomized controlled trial. *Advances in Medical Education and Practice*. 5: 257-262.

37. Heiland DH, Petridis AK, Maslehaty H, Thissen J, Kinzel A, Scholz M, Schreiber L (2014). Efficacy of a new video-based training model in spinal surgery. *Surgical Neurology International*. 5(1)

38. Philips J, Brook A, Tseng I, Sharpe Jr RE, Fein-Zachary V, Slanetz PJ, Mehta TS (2016). Educational Videos: An Effective Tool to Improve Training in Interventional Breast Procedures. *Journal of the American College of Radiology*. 13: 719-724.

39. Mehrpour SR, Aghamirsalim M, Motamedi SMK, Larijani FA, Sorbi R (2013). A Supplemental Video Teaching Tool Enhances Splinting Skills. *Clinical Orthopaedics and Related Research*. 471: 649-654.

40. Mpotos N, Yde L, Calle P, Deschepper E, Valcke M, Peersman W, Herregods L, Monsieurs L (2013). Retraining basic life support skills using video, voice feedback or both: A randomized controlled trial. *Resuscitation*. 84: 72-77.

41. Srivastava G, Roddy M, Langsam D, Agrawal D (2011). An Educational Video Improves Technique in Performance of Pediatric Lumbar Punctures. *Pediatric Emergency Care*. 28(1): 12-16.

42. Nousiainen M, Brydges R, Backstein, Dubrowski A (2008). Comparison of expert instruction and computer-based video training in teaching fundamental surgical skills to medical students. *Surgery*. 143(4): 539-544.

43. Jowett N, LeBlanc V, Xeroulis G, MacRae H, Dubrowski A (2007). Surgical skill acquisition with self-directed practice using computer-based video training. *The American Journal of Surgery*. 193: 237-242.

44. Bandura A (1994). Self-efficacy. *Encyclopedia of Human Behavior*. 4: 71-81. New York: Academic Press.

45. Turan S, Valcke M, Aper Leen, Koole S, Derese A (2012). Studying self-efficacy beliefs in medical education. *Procedia – Social and Behavioral Sciences*. 93: 1311-1314.

46. Randler X, Demirhan E, Wust-Ackermann P, Desch IH (2016). Influence of a Dissection Video Clip on Anxiety, Affect, and Self-Efficacy in Educational Dissection: A Treatment Study. *CBE Life Sciences Education*. 15(1).

47. Chan T, Sebok-Syer S, Thoma B, Wise A, Sherbino J, Pusic M (2018). Learning Analytics in Medical Education Assessment: The Past, the Present, and the Future. *AEM Education and Training*. Published online: https://doi.org/10.1002/aet2.10087

48. Maloney S, Nicklen P, Rivers G, Foo J, Ooi YY, Reeves S, Walsh K, Ilic D (2015). A Cost-Effectiveness Analysis of Blended Versus Face-to-Face Delivery of Evidence-Based Medicine to Medical Students. *Journal of Medical Internet Research*. 17(7): e182.

49. Guo PJ, Kim J, Rubin R (2014). How video production affects student engagement: an empirical study of MOOC videos. *Proceedings of the first ACM conference on Learning @ scale conference*. 41-50.

50. Nematollahi S, St John P, Adamas-Rappaport W (2015). Lessons learned with a flipped classroom. *Medical Education*. 49:1143.

51. Lau KHV, Farooque P, Leydon G, Schwartz ML, Sadler RM, Moeller JJ (2017). Using learning analytics to evaluate a video-based lecture series. *Medical Teacher*. 40(1): 91-98.

52. Lobel DA, Kahn M, Rosen CL, Pilitsis R, Pilitsis J (2015). Medical Student Education in Neurosurgery: Optional or Essential? *Teaching and Learning in Medicine*. 27(2): 201-204.

53. Gibbs TS, Fleische Jr AB, Feldman SR, Sam MC, O'Donovan CA (2003). Healthcare utilization in patients with migraine. *Headache*. 43: 330–335.

54. Evans RW (1996). Diagnostic testing for the evaluation of headaches. *Neurologic Clinics*. 14: 1–26.

55. Kowalski RG, Claassen J, Kreiter KT, Bates JE, Ostapkovich ND, Connolly ES,

Mayer SA (2004). Initial misdiagnosis and outcome after subarachnoid hemorrhage. *Journal of the American Medical Association*. 291: 866–869.

56. Stiell IG, Wells GA, Vandemheen K, Laupacis A, Brison R, Eisenhaure MA, Greenberg GH et al (1997). Variation in ED use of computed tomography for patients with minor head injury. *Annals of Emergency Medicine*. 30: 14–22.

57. Gardner A, Gardner E, Morley T (2011). Cauda equina syndrome: A review of the current clinical and medico-legal position. *European Spine Journal*. 20: 690–7.

58. Resnick DK (2000). Neuroscience education of undergraduate medical students. Part I: Role of neurosurgeons as educators. *Journal of Neurosurgery*. 92: 637–41.

59. Fox BD, Amhaz HH, Patel AJ, Fulkerson DH, Suki D, Jea A, Sawaya RE (2011). Neurosurgical rotations or clerkships in US medical schools. *Journal of Neurosurgery*. 114: 27–33.

60. Pilitsis JG, Beverly S, Mazzola C, Ashley Jr. W, Colen C, Asadi K, Steinmetz M (2013). Neurosurgeon and student perspective on the current medical education in neurosurgery. *AANS Neurosurgeon*. 22.

61. SelSignore LA, Wolbrink TA, Zurakowski D, Burns JP (2016). Test-Enhanced E-Learning Strategies in Postgraduate Medical Education: A Randomized Cohort Study. *Journal of Medical Internet Research*. 18(1): e299.

62. Mayer RE (2014). Principles for Multimedia Learning. Accessed April 4, 2018. Lecture and article available online at: https://hilt.harvard.edu/blog/principles-multimedia-learning-richard-e-mayer.

63. Congress of Neurological Surgeons (2018). Medical Student Curriculum in Neurosurgery. Accessed April 4, 2018. Available online at:

https://www.cns.org/careers-training/academic/medical-student-curriculum-neurosurgery.

64. Leung FH, Savithiri (2009). Spotlight on focus groups. *Canadian Family Physician*. 55(2): 218-219.

65. Omni (2018). Toolkit for Conducting Focus Groups. Report.

66. Day T, Tosey P (2011). Beyond SMART? A new framework for goal setting. *The Curriculum Journal*. 22(4): 515-534

67. Magee C, Rickards G, Byars LA, Artino AR (2013). Tracing the Steps of Survey Design: A Graduate Medical Education Research Example. *Journal of Graduate Medical Education*. Editorial March 2013.

68. Paniagua MA, Swygert, KA (2016). Constructing Written Test Questions For the Basic and Clinical Sciences. *NBME Guide.*

69. Al-Rukban (2006). Guidelines for the Construction of Multiple Choice Questions Tests. *Journal of Family and Community Medicine*. 13(3): 125-133.

70. Rowbothan M, Schmitz GS (2013). Development and Validation of a Student Self-efficacy Scale. *Journal of Nursing & Care*. 2(1).

71. Dandavino M, Young M, Gosselin R, Snell L, Bhanji F (2013). Development and validation of a self-efficacy scale for clinical decision-making in pediatrics. *Paediatrics & Child Health*. 18(4): 184-188.

72. Schwarzer R., & Jerusalem M. (1995). *Generalized Self-Efficacy Scale*. In J. Weinman, S. Wright, & M. Johnston, Measures in health psychology: A user's portfolio. Causal and control beliefs (pp. 35-37). Windsor, UK: NFER-NELSON.

73. Knowles M (1980). *The modern practice of adult education: Andragogy versus pedagogy. Rev. and updated ed.* Englewood Cliffs, NJ: Cambridge Adult Education.

74. TEAL (Teaching Excellence in Adult Literacy) (2011). Adult Learning Theories. *TEAL Center Fact Sheet* No. 11.

75. Knowles M et Al (1984). *Andragogy in action: Applying modern principles of adult learning.* San Francisco: Jossey-Bass.

76. Cross K. P. (1981). *Adults as learners: Increasing participation and facilitating learning.* San Francisco: Jossey-Bass.

77. Cebeci S, Dane S, Kaya M, Yigitoglu R (2013). Medical Students' Approaches to Learning and Study Skills. *Proceedia – Social and Behavioral Sciences*. 93: 732-736

Appendices

Appendix A. Surveys, Questionnaires and Tests

Needs assessment survey

Default Question Block

Please enter the year you graduated medical school.

During medical school, did you receive any formal training in neurosurgery?

If so, approximately how many days of neurosurgery did you experience?

Concept videos are educational videos that are intended to teach a given topic

Have you ever used concept videos (i.e. short educational videos) as a learner?

Block 2

Please rate how useful these videos were to your learning (0= Not useful, 10 = Extremely Useful)

Please comment on why these videos were useful/not useful.

Important concepts in neurosurgery and neurology

How confident would you say that you are with the following concepts?

	Confide	Not
The pathophysiology and treatment of hydrocephalus	○	○
The pathophysiology and treatment of intracranial hematoma/hemorrhage	○	○
	○	○
Recording and interpreting the Glasgow Coma Scale score	○	○

Important concepts in neurosurgery and neurology

It is essential for a clinician to have a basic understanding of...

	Agree	Neither agree nor disagree	Disagree
The pathophysiology and treatment of hydrocephalus	○	○	○
The pathophysiology and treatment of intracranial hematoma/hemorrhage	○	○	○
Recording and interpreting the Glasgow Coma Scale score	○	○	○
	○	○	○

Important concepts in neurosurgery and neurology

I would be interested in brief educational videos that review and consolidate the essentials of...

	Ye	N
Hydrocephalus	○	○
Intracranial	○	○
hematoma/hemorrhage The	○	○
Glasgow Coma Scale	○	○

Additional comments and feedback

Please use the space below to add any additional thoughts, or any other neurosurgical concepts on which you would like to receive more training.

Self-efficacy: Neurosurgery Concepts

Name: …………………………………………………………………........

Date: ……………………………………………………………………...

For each of the options below, please ***circle*** *the level to which you agree/disagree with a statement. Please* ***only circle one item*** *on the scale for each option. Please do so for all options.*

1. *I have adequate knowledge of the basics of neurosurgery*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

2. *I am able to adequately apply the steps of diagnosis and suggest a treatment plan for hydrocephalus*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

3. *I am able to adequately apply the steps of diagnosis and suggest a treatment plan for different types of intracranial hematoma*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

4. *I am able to adequately apply the steps of using and interpreting the Glasgow Coma Scale*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

5. *I am able to adequately apply the steps of interpreting common neurosurgical pathology using commonly used radiological modalities*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

6. *I am able to search literature and resources relevant to a neurosurgical problem*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree**

Neurosurgery Concepts: The Essentials of Neuro-imaging

Name: …………………………………………………………………….…

Date: ………………………………………………………………………..

For each of the questions below, please circle the Single Best Answer. There is ***no more than ONE*** *correct answer for each question. Please attempt all questions.*

1. With regards to spinal X-rays, which of the following statements is correct?

a) There are six cervical vertebrae.
b) The C1 vertebra has a structure on it called the odontoid peg.
c) Compared to the lumbosacral vertebrae, the thoracic vertebrae are more readily visible on spinal X-rays.
d) There are more sub-axial vertebrae than there are axial vertebrae.

2. With regards to CT scans, which of the following statement is **NOT** correct?

a) The attenuation properties of the X-rays used are measured in Hounsfield Units.
b) On a plain CT head, denser tissues appear white.
c) On a plain CT head, fluid appears white.
d) Bone corresponds to -1000 units and air +1000 units.

3. With regards to Magnetic Resonance Imaging (MRI), which of the following statements is correct?

a) Contrast agent normally passes readily through the blood brain barrier.
b) The pituitary is within the blood brain barrier.
c) Proton spin differs between tissues.
d) There are four main acquisitions.

4. With regards to skull fractures, which of the following is **NOT** a main type of skull fracture?

a) Depressed skull fracture
b) Diastatic skull fracture
c) Comminuted skull fracture
d) Linear skull fracture

5. A patient is brought into the ED after suffering an accident on the golf course. A golf ball hit the man’s temple, after which he fell unconscious to the ground. Radiological imaging of the head shows a hyperdense lesion in the temporal area of the cranium, which appears to be limited by the suture lines of the brain. What is the most likely diagnosis?

a) Acute subdural hematoma
b) Epidural hematoma
c) Subarachnoid hemorrhage
d) Traumatic Brain Injury (TBI)

6. Subdural hematomas most likely occur as the result of injury to which blood vessel(s)?

a) Middle meningeal artery
b) Middle cerebral artery
c) Vertebral veins
d) Bridging veins

7. What would be the most likely and appropriate descriptive term for the appearance of an acute subdural hematoma on a non-contrast CT scan?

a) Hypodense
b) Hyperdense
c) Isodense
d) Heterodense

8. With regards to subarachnoid hemorrhage, the blood collects in the space between:

a) The arachnoid membrane and pia mater
b) The arachnoid membrane and the dura mater
c) The arachnoid membrane and the brain parenchyma
d) The arachnoid membrane and the skull

9. Overall, what is the most common underlying cause of intracerebral hemorrhage?

a) Ruptured cerebral aneurysm
b) Hypertension
c) Vasculitis
d) Arterio-Venous Malformation (AVM)

10. A patient is admitted to the emergency department with a suspected subarachnoid hemorrhage based on history and examination. What is the most appropriate next diagnostic investigation?

a) MRI Brain with contrast
b) CT-Angiogram of Head
c) Lumbar puncture (LP)
d) Non-contrast CT Head

11. A patient is admitted to the emergency department with a suspected subarachnoid hemorrhage based on history and examination. Initial radiological imaging confirms a subarachnoid hemorrhage. What is the most appropriate next diagnostic investigation?

a) MRI Brain with contrast
b) CT-Angiogram of Head
c) Lumbar puncture (LP)
d) Non-contrast CT Head

12.With regards to arterio-venous malformations, what is the approximate yearly risk of rupture?

a) 0.4 %
b) 4% c)
14% d)
44%

13. A patient has had an MRI Brain performed, and you are asked to present the radiology report for the morning meeting. An incidental lesion has been found, which is described as 'cystic vascular sinusoids linked with a vascular endothelial layer, with no neural tissue in association with it'. What type of lesion does this most likely describe?

a) Capillary telangiectasia
b) Arterio-venous malformation
c) Cavernous angioma
d) Venous angioma

14. A patient has had an MRI Brain performed, and you are asked to present the radiology report for the morning meeting. An incidental lesion has been found, which is described as 'large veins in the white matter surrounding the ventricles'. What type of lesion does this most likely describe?

a) Capillary telangiectasia
b) Arterio-venous malformation
c) Cavernous angioma
d) Venous angioma

15. A patient has had an MRI Brain performed and you are asked to present the radiology report for the morning meeting. An incidental lesion has been found, which is described as 'dilated capillaries in the pons, with normal neural tissue interspersed within'. What type of lesion does this most likely describe?

a) Capillary telangiectasia
b) Arterio-venous malformation
c) Cavernous angioma
d) Venous angioma

16. Which of the following is not a type of intra-axial brain tumor?

a) Meningioma
b) Glioblastoma
c) Oligodendroglioma
d) Ependymoma

17. A patient has had an MRI brain which confirms the presence of a brain tumor. Reading the radiology report, it is described as a 'poorly defined isodense entity in the white matter, with surrounding edema'. What is the most likely diagnosis?

a) Lymphoma
b) Glioma
c) Neuronal origin tumor
d) Metastasis

18. A child has had an MRI brain which confirms the presence of a brain tumor. Reading the radiology report, it is described as a 'well-defined cystic lesion with an enhancing nodule within, near the third ventricle'. What is the most likely diagnosis?

a) Astrocytoma
b) Glioblastoma multiforme
c) Pilocytic astrocytoma
d) Oligodendroglioma

19. A patient has had an MRI brain which confirms the presence of a brain tumor. Reading the radiology report, it is described as a 'patchy, or heterogeneous lesion in the right cerebral hemisphere, with areas of calcification within'. What is the most likely diagnosis?

a) Astrocytoma
b) Glioblastoma multiforme
c) Pilocytic astrocytoma
d) Oligodendroglioma

20. A patient has had a non-contrast CT head which confirms the presence of a brain tumor. Reading the radiology report, it is described as an 'isodense tumor with areas of hyperdensity within directly adjacent to the fourth ventricle'. What is the most likely diagnosis?

a) Lymphoma
b) Glioblastoma multiforme
c) Metastasis
d) Ependymoma

21. Overall, cerebral metastases comprise approximately what quantity of all brain tumors?

a) 5-10%
b) 25-30%
c) 40-50%
d) More than 50%

22. An old lady is admitted to the ED after she has fallen over and hit her head. A CT head is performed, which shows no evidence of an intracranial hematoma or skull fracture. However, there is an incidental finding of a lesion on the scan. In the radiology report, it is described as 'hyperdense, well-demarcated, right adjacent to the dura, with calcification of the adjacent bone'. What is the most likely diagnosis?

a) Glioblastoma multiforme
b) Oligodendroglioma
c) Meningioma
d) Vestibular schwannoma

Neurosurgery Concepts: Intracranial hemorrhage

Name: ....

Date: ....

For each of the questions below, please circle the Single Best Answer. There is ***no more than ONE*** *correct answer for each question. Please attempt all questions.*

1. A neurosurgical operation is performed, and the surgeon opens up the scalp and removes a flap of the skull. Upon doing this, a white, glossy membrane becomes visible underneath the skull. What is this structure called?

a) Filum terminale
b) Pia mater
c) Arachnoid mater
d) Dura mater

2. The subdural space refers to the space that is created between which two membranes?

a) Dura mater and pia mater
b) Arachnoid mater and pia mater
c) Dura mater and arachnoid mater
d) Cranium and dura mater

3. The subarachnoid space refers to the space that is created between which two membranes?

a) Dura mater and pia mater
b) Arachnoid mater and pia mater
c) Dura mater and arachnoid mater
d) Cranium and arachnoid mater

4. Epidural hematomas are normally the result of the rupture or shearing of which blood vessel?

a) Middle cerebral vein
b) Middle cerebral artery
c) Middle meningeal vein
d) Middle meningeal artery

5. The ‘lucid’ interval refers to the brief loss of consciousness following a traumatic event, followed by regaining consciousness, and then going into coma, and occurs in:

a) 100% of patients with epidural hematomas
b) 50% of patients with epidural hematomas
c) 10-25% of patients with epidural hematomas
d) 5-10% of patients with epidural hematomas

6. With regards to anatomical location, most epidural hematomas occur along the:

a) Anterior aspect of the skull
b) Lateral aspect of the skull
c) Posterior aspect of the skull
d) Occipital aspect of the skull

7. One of the possible neurological complications of an epidural hematoma is pupillary dilation. This occurs as a result of compression of which nerve?

a) Oculomotor nerve
b) Optic nerve
c) Ciliary nerve
d) Facial nerve

8. The initial preferred radiological modality to investigate a potential epidural hematoma is:

a) Plain skull X-ray
b) Plain CT Head
c) MRI Brain with contrast
d) CT Angiography

9. An epidural hematoma can often have a classic appearance on initial radiological imaging. What is this classic term?

a) ‘Crescent-shaped’
b) ‘Biconvex/lenticular’
c) ‘Heterogeneously concave’
d) ‘Semi-cystic’

10. The most common way of accessing the cranium to allow evacuation of an epidural hematoma is:

a) Cranial burrholes
b) Craniotomy
c) Craniectomy
d) Hemicraniectomy

11. Which of the following statements is **NOT** correct?

a) Epidural hematomas have a high mortality rate.
b) Surgical treatment is normally required.
c) Not all patients have a 'lucid interval'.
d) Epidural hematomas exclusively occur as a result of rupture of the middle meningeal artery.

12. With regards to subdural hematomas, which of the following statements is correct)?

a) Compared to acute subdural hematomas, chronic subdural hematomas occur more frequently as a result of significant impact trauma.
b) Acute subdural hematomas and chronic subdural hematomas have similar prognoses.
c) Compared to males, females are more at risk of acute subdural hematomas.
d) Compared to acute subdural hematomas, chronic subdural hematomas appear more dense on radiological imaging.

13. With regards to timeline of clinical presentation, acute subdural hematomas are defined as having occurred within:

a) 3 days
b) 7 days
c) 10 days
d) 14 days

14. The most common way of accessing the cranium to allow evacuation of a chronic subdural hematoma is:

a) Cranial burrholes
b) Craniotomy
c) Craniectomy
d) Hemicraniectomy

15. A subdural hematoma can often have a classic appearance on initial radiological imaging. What is this classic term?

a) 'Crescent-shaped'
b) 'Biconvex/lenticular'
c) 'Heterogeneously concave'
d) 'Semi-cystic'

16. With regards to subdural hematomas, which of the following statements is **NOT** correct?

a) Chronic subdural hematomas generally have a worse prognosis than epidural hematomas.
b) At presentation, acute subdural hematomas imply a higher level of underlying brain damage than chronic subdural hematomas.
c) Chronic subdural hematomas may sometimes be treated conservatively.
d) Midline shift is a significant finding on neuro-imaging.

17. With regards to subarachnoid hemorrhage, please select the statement that is **NOT** correct:

a) It may be as the result of trauma or occur spontaneously.
b) A large proportion of patients die before they reach hospital.
c) Ruptured arterio-venous malformations are the most common underlying pathology.
d) Oral contraceptives increase the risk of subarachnoid hemorrhage.

18. The preferred initial radiological modality to investigate a potential subarachnoid hemorrhage is:

a) Plain skull X-ray
b) Plain CT Head
c) MRI Brain with contrast
d) CT Angiography

19. A patient is admitted to the ED complaining of a 'thunderclap' headache, complaining of neck stiffness and photophobia, and subarachnoid hemorrhage is suspected. Initial radiological imaging does not detect any signs of subarachnoid hemorrhage, and the patient is now asymptomatic. Given that the diagnosis is suspected, what would be the next most appropriate step?

a) Discharge the patient and book into urgent follow-up clinic
b) Neurological observations for 24 hours, and send home if asymptomatic
c) Perform a lumbar puncture
d) Perform an angiography

20. With regards to 'Triple H-therapy', which is **NOT** a constituent component?

a) Hypertension
b) Hypovolemia
c) Hemodilution
d) Hyponatremia

21. The cerebrospinal fluid (CSF) of a patient with a recent subarachnoid hemorrhage is **NOT** expected to exhibit:

a) High red blood cell count
b) Low opening pressure
c) High protein content
d) Normal glucose levels

Neurosurgery Concepts: Hydrocephalus

Name: ………………………………………………………………….......

Date: ……………………………………………………………………...

*For each of the questions below, please circle the Single Best Answer. There is **no more than ONE** correct answer for each question. Please attempt all questions.*

1. Cerebrospinal fluid (CSF) production occurs mainly in the following anatomical location:

a) Ependymal cells
b) Choroid Plexus
c) Aqueduct of Sylvius
d) Arachnoid granulations

2. Cerebrospinal fluid (CSF) absorption occurs mainly in the following anatomical location:

a) Ependymal cells
b) Choroid Plexus
c) Aqueduct of Sylvius
d) Arachnoid granulations

3. With regards to hydrocephalus, which one of the following statements is **NOT** correct?

a) Obstructive hydrocephalus implies that there is obstruction of the CSF flow in the ventricular system.
b) Non-obstructive hydrocephalus implies that there is dysfunctional absorption at the level of the absorption.
c) Hydrocephalus is synonymous with raised intracranial pressure.
d) There is a circa 1% prevalence of hydrocephalus in the population.

4. With regards to hydrocephalus, which one of the following is **NOT** a cause of obstructive hydrocephalus?

a) Brain tumor
b) Stenosis of the aqueduct of Sylvius
c) Arnold Chiari malformation
d) Tuberculosis meningitis

5. With regards to hydrocephalus, which one of the following is a cause of non-obstructive (communicating) hydrocephalus?

a) Arnold Chiari malformation
b) TB abscess
c) Subarachnoid hemorrhage
d) Astrocytoma

6. Patients with hydrocephalus may exhibit an 'upgaze palsy' when clinically examined. This is due to pressure on which nerve?

a) Optic nerve
b) Abducens nerve
c) Oculomotor nerve
d) Ophthalmic nerve

7. With regards to hydrocephalus, which one of the following statements is **NOT** correct:

a) Hydrocephalus is mainly treated with conservative or medical intervention.
b) Acetazolamide can be used to treat hydrocephalus.
c) Lumbar punctures can be used to treat acute hydrocephalus.
d) Lumbar punctures can be dangerous to perform in hydrocephalus.

8. With regards to hydrocephalus, which one of the following statements is **NOT** correct?

a) External ventricular drains are not used for non-obstructive (communicating) hydrocephalus.
b) Ventricular-peritoneal shunts are the most common type of shunts used in patients with hydrocephalus.
c) Endoscopic Third Ventriculostomy (ETV) is most commonly used for non-obstructive (communicating) hydrocephalus.
d) Alzheimer's Disease may be the differential diagnosis for hydrocephalus.

9. With regards to hydrocephalus, which of the following would **NOT** be a typical radiological sign?

a) Enlarged temporal horns of the lateral ventricles
b) Periventricular low density
c) 'Mickey Mouse' ear appearance of the anterior horns of the lateral ventricles
d) 'Pepper pot' cranium

10. With regards to Normal Pressure Hydrocephalus (NPH), which of the following is **NOT** part of the classical clinical triad of presentation?

a) Gait disturbance
b) Headache
c) Dementia
d) Urinary incontinence

Neurosurgery Concepts: Glasgow Coma Scale

Name: ………………………………………………………………....

Date: ……………………………………………………………………...

For each of the questions below, please circle the Single Best Answer. There is ***no more than ONE*** *correct answer for each question. Please attempt all questions.*

1. The Glasgow Coma Scale (GCS) is used to assess patients in three domains: Eyes, Verbal and Motor. The maximum possible score is 15, composed of each of the scores from these three domains.

   Which of the following options contains the correct composition of the score?

   a) Eyes: 5 Verbal: 5 Motor: 5
   b) Eyes: 6 Verbal: 5 Motor: 4
   c) Eyes: 6 Verbal: 6 Motor: 3
   d) Eyes: 4 Verbal: 5 Motor: 6
   e) Eyes: 5 Verbal: 4 Motor: 6

2. A 25-year old motorcyclist is brought into hospital by ambulance following a head-on collision with a truck on a main street. The collision took place at low speed, and the motorcyclist was wearing a helmet, so apart from having a mild/moderate headache, the motorcyclist reported no injuries. On arrival to the Emergency Department, he is orientated, awake and talking to the triage nurse, albeit slightly confused. Whilst waiting to be seen by the Emergency Department doctor, the motorcyclist suddenly collapses on the floor. A crash call is made, and the neurosurgical doctor, who happens to be in the adjacent cubicle assessing another patient, assesses the patient. On assessment, the patient only opens his eyes to pain, is muttering incomprehensible words, and localizes pain.

   Which of the following options would most accurately describe his Glasgow Coma Scale Score?

   a) Eyes: 2 Verbal: 2 Motor: 5
   b) Eyes: 2 Verbal: 1 Motor: 5
   c) Eyes: 2 Verbal: 2 Motor: 3
   d) Eyes: 2 Verbal: 3 Motor: 5
   e) Eyes: 5 Verbal: 4 Motor: 6

3. Regarding the Glasgow Coma Scale (GCS), which of the following options is correct?

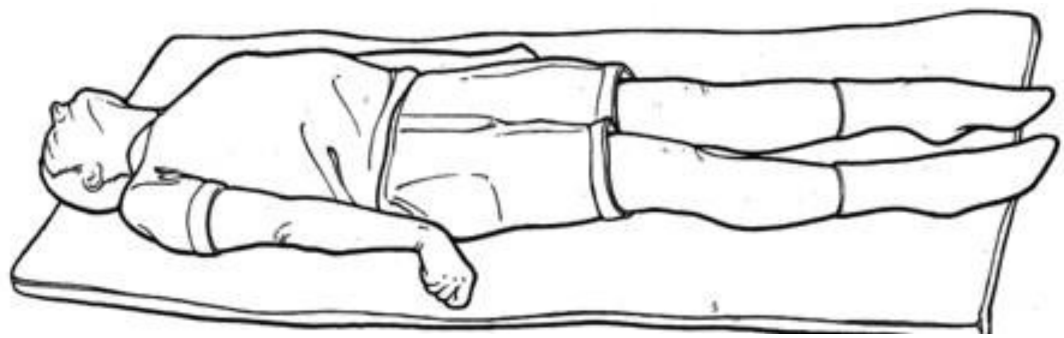
   a) A CT head scan is essential for assessment of the GCS score.
   b) The lowest possible score is zero (0).
   c) The total, aggregated score is the most useful aspect.
   d) GCS does not correlate well with extra-cranial complications.
   e) A total, aggregated score of less than 8 normally indicates severe head injury.

4. The image above illustrates a patient with the following type of posturing:

   a) Dysdiadochokinesia
   b) Decorticate posturing
   c) Decerebrate posturing
   d) Diencephalic posturing

5. Please indicate the Glasgow Coma Scale Motor component score of the patient illustrated in question 4:

   a) 2
   b) 3
   c) 4
   d) 5



6. The image above illustrates a patient with the following type of posturing:

   a) Dysdiadochokinesia
   b) Decorticate posturing
   c) Decerebrate posturing
   d) Diencephalic posturing

7. Please indicate the Glasgow Coma Scale Motor component score of the patient in question 6:

   a) 2
   b) 3
   c) 4
   d) 5

8. Regarding the Glasgow Coma Scale, please select the best answer:

   a) The Glasgow Coma Scale is not suitable for pediatric patients.
   b) The Glasgow Coma Scale has little utility, unless all the domains (Eyes, Verbal and Motor) can be measured.
   c) Even if one side of the body has no motor response, the motor response on the other side of the body can be recorded as normal, if normal.
   d) The Glasgow Coma Scale is useful to guide management of patients, but has little value in estimating prognosis of a patient.

9. A patient is brought into the ED after a motorcycle accident. As you apply pressure to the supraorbital ridge of the patient, he moves his hand up towards his face. How would you record this on the Glasgow Coma Scale?

   a) Extension
   b) Decorticate posturing
   c) Flexion
   d) Localizing response
   e) Abnormal flexion

10. On the morning rounds, the attending physician examines a patient neurologically. As she applies pressure to the patient's nailbed, the patient's elbow bends and the arm moves rapidly away from the body. The attending physician calls this 'normal flexion'. What would constitute the 'normal flexion' score for the 'Motor' component of the Glasgow Coma Scale?

a) 2
b) 3
c) 4
d) 5
e) 6

11. One of the nurses on the unit has called you to see a patient who he is worried about. He tells you that the patient scores 10 on the Glasgow Coma Scale. When asked to break down the score, he says that the patient's eyes open to painful stimuli, utters a few words, but not complete sentences, and localizes to pain. What would the correct breakdown of the components of the score be?

a) E2V2M4
b) E2V3M5
c) E2V4M5
d) E2V4M6

12. Which of these patient's would score the highest in the motor component of the Glasgow scale?

a) Right arm localizing, no movement left arm
b) Right arm flexing, left arm flexing
c) Right arm extending, left arm flexing
d) Right arm extending, left arm extending

13. A patient is admitted to the ED after a brawl in a bar. As you are about to assess his level of consciousness, you notice that his eyes are very swollen, and he is unable to open them. How would you record this in the eye component of the Glasgow Coma Scale?

a) No response
b) Eye movement painful
c) Eyes Not Testable (NT)
d) 3

14. What is the correct sequence of responses as assessed by the eye component of the Glasgow Coma Scale?

   a) Spontaneous, to sound, to pressure/pain, no response
   b) Spontaneous, no response, to sound, to pressure/pain
   c) To sound, to pressure/pain, to movement, no response
   d) To sound, to movement, to pressure/pain, no response

15. You are asked to examine a patient pre-operatively for the evacuation of a subdural hematoma. As you approach the patient, you can see that the he is lying in bed, awake, and looking at you as you enter the room. What number would you record for this status in the eye component of the Glasgow Coma Scale?

   a) 1
   b) 2
   c) 3
   d) 4

Answer Key - MCQs

Hydrocephalus

1) B
2) D
3) C
4) D
5) C
6) B
7) A
8) C
9) D
10) B

Neuroimaging

1) D
2) D
3) C
4) C
5) B
6) D
7) B
8) A
9) B
10) D
11) B
12) B
13) C
14) D
15) A
16) A
17) B
18) C
19) D
20) D
21) B
22) C

Intracranial hemorrhage

1. D
2. C
3. B
4. D
5. C
6. B
7. B
8. B
9. B
10. B
11. D
12. C
13. A
14. A
15. A
16. A
17. C
18. B
19. C
20. D
21. B

Glasgow Coma Scale

1) D
2) A
3) E
4) B
5) B
6) C
7) A
8) C
9) D
10) C
11) B
12) A
13) C
14) A
15) D

Appendix B. Scripts and Storyboards

INTRODUCTION VIDEO

Hello! I am Dr Gustaf Axelsson. Having experienced neurosurgery both as a medical student and trainee, the field has never seized to fascinate me. However, as a medical student I always found neurosurgery to be somewhat daunting, both in terms of understanding all the anatomy involved, as well as linking this to clinical diagnoses and subsequent clinical and operative management – all while challenged by the oftentimes hectic working environment in the neurosurgery department.

I would like to welcome and congratulate you all to decide to take part in this educational program, developed here at Harvard Medical School and Massachusetts General Hospital. The goal with these videos is not to make you all expert neurosurgeons. However, knowledge of the fundamentals underlying the most common neurosurgical diagnoses is key to any clinician, whether you decide to work in the emergency room, within primary care, or in general surgery, and many more specialties.

There are four videos in this first part of this series, covering hydrocephalus, the Glasgow Coma Scale score, intracranial hemorrhage, and the essentials of intracranial neuroimaging.

I hope you will find the videos and formative assessment materials both useful and enjoyable. And please, do not be afraid to reach out to me if you have any questions, or feedback. Enjoy!

THE GLASGOW COMA SCALE SCORE

INTRODUCTION

SLIDE 2

The Glasgow Coma Scale score was (rather unsurprisingly) developed in Glasgow in the 1970s as a way to create a measure and assessment tool of a patient's level of consciousness that could be communicated easily amongst professionals, and to minimize what we call inter-observer variability – which is what it says on the tin – the difference in results between two or more individuals measuring the same thing. Whether working in a neurosurgical unit, an intensive care unit, or indeed on a general ward, accurate assessment and consistent measure of a patient's level of consciousness can be a matter of life or death, as it often directly will impact subsequent management of that patient, whether medical or operative.

SLIDE 3

In this video, I aim to discuss some of the underlying principles of the scale, go through a few clinical cases, and then discuss some tips and tricks that I have learnt through the years. However, this video is only the start. As with any skill, mastery requires real life practice. So after this video, I want you all to go out and measure the Glasgow Coma Scale as much as you can, whether in the clinical environment, or on your friends and family.

SLIDE 4

THE SCALE

The Glasgow Coma Scale is made up of three components that you assess as a clinician. These are the Motor part of the score (6 points), the Verbal part of the score (5 points), and the Eye part (4 points). A person, who is fully alert and well, is thus expected to score 15 points on the Glasgow Coma Scale. The lowest score possible is 3, which would imply that the person scores 1 point in the Motor Domain, one point in the Verbal Domain, and one point in the Eye Domain.

SLIDE 5

Let's have a look at a table summarizing the Glasgow Coma Scale score.

Points	Best Eye Opening	Best Verbal Response	Best Motor Response
6	-	-	Obeys
5	-	Oriented	Localizes pain
4	Spontaneous	Confused	Withdraws to pain
3	To speech	Inappropriate	Flexor (decorticate)
2	To pain	Incomprehensible	Extensor (decerebrate)

1	None	None	None

As you can see, the **motor component** is made up of 6 points, the Verbal component is made up of 5 points and the Eye response component is made up by 4 points.

Let's start with the **Motor component**, which is the most important part of the scale, where we assess a patient for a motor response by stimulating this response.

SLIDE 6

- A patient who is alert, and obeying motor commands, for example, touching his or her nose, will **score 6** in this domain.

SLIDE 7

- A patient who has a depressed level of consciousness will not be able to obey a command. Thus, by applying supraorbital pressure, we can assess for a localizing response to pain. For example, if I pinch a patient's earlobe, they should move a limb up towards the pain point to **score 5** in this domain.

SLIDE 8

- If, instead of localizing, a patient does a withdrawing motion (for example by pulling his/her arm away when we apply pressure to the nailbed), this will **score a 4** on the GCS scale.

SLIDE 9

- A **score of 3** is constituted by what was previously called a 'decorticate' movement – but nowadays a more practical term is used – namely abnormal flexion.

SLIDE 10

- This abnormal flexion is due to disinhibition by removal of the corticospinal pathways above the midbrain. Clinically, this means that the patient will flex their upper limbs abnormally as demonstrated here. We see this slow flexion of the arm, wrist and fingers along with an element of adduction. However, in the lower limb, we see abnormal extension instead, with internal rotation and plantar flexion.

SLIDE 11

- If a patient exhibits what was previously called decerebrate movement – and now is called abnormal extension – they will **score a 2** on the Glasgow Coma Scale. This **abnormal flexion** is illustrated here: we see what is called *opisthotonos* (which is extension of the head and trunk), clenching of the teeth, extension and adduction, and internal rotation (or hyperpronated) arms, with flexed fingers and wrists. We also see **abnormal extension** of the lower limbs, with internal rotation, feet plantar flexed and inverted, and the toes plantar flexed.

SLIDE 12

This posturing is due to disinhibition of the vestibulospinal tract (which is more caudal, or lower down in the central nervous system anatomically), and disinhibition of the pontine reticular formation. This is all in turn caused by disinhibition of the medullary reticular formation. I would advise you to look at a few images of patients with both of these syndromes. Memorizing all the details of the anatomy is most certainly not essential. My advice is that you instead just have an image in your head of how these two types of posturing look clinically.

SLIDE 13

- If the patient has no motor response at all, they will **score a 1** on the scale. This could be caused by some obvious factors, such as deep coma or death, but in the awake patient, it is important to exclude things, such as spinal cord transection.

SLIDE 14

The **voice domain** of the scale is perhaps more straightforward.

SLIDE 15

- The normally conversant patient will **score a 5**.

SLIDE 16

- A patient who is confused, but speaks intelligibly, will **score a 4**.

SLIDE 17

- A patient, who will response to voice, but utter inappropriate words out of context, will **score a 3**.

SLIDE 18

- A patient, who uses his/her voice, but says incomprehensible words – colloquially called jibberish – will **score a 2.**

SLIDE 19

- No verbal effort will render the patient a score **1** on the Glasgow Coma Scale.

SLIDE 20

Finally, we move onto to assessing the patient’s **eye response**.

SLIDE 21

- A patient, who is awake with their eyes opened, will **score a 4**.

SLIDE 22

- If the patient only opens his or her eyes prompted by you talking to them, they will **score a 3**. This could of course be the asleep patient – we are all GCS 14, when we sleep.

SLIDE 23

- A patient, who only opens their eyes when you elicit a painful stimulus, such as pressing the nailbed, will **score a 2** on the scale.

SLIDE 24

- Finally, no response will render a score **1**.

As mentioned previously, it is important to really give the patient the opportunity to respond to pain. This of course means that the pain you apply must be sufficient, but of course not excessive.

KEY POINTS TO REMEMBER

SLIDE 25

At this point, it is important to remember a couple of key points. Firstly, based on extensive studies of outcomes done in patients with head trauma, the number of points in each domain reflects the sensitive and predictive nature of the score of each domain. Although it is important to consider the whole scale, in practice, losing one point within the Motor or Verbal component could be potentially more serious than losing one point in the Eye component.

SLIDE 26

However, secondly, when assessing and reporting the Glasgow Coma Scale, it is important to not only communicate the total score (e.g. 14), but to communicate the score within each domain. A score of 14 could be made up of various combinations of the components' scores. For example, a patient who is asleep with his or her eyes closed, may score 14, because of losing one point in the Eye domain, and we might not be so worried that something is wrong with that particular patient. However, another patient might also score 14 as a total score, but does this because of a lack of ability to obey commands of moving his or her limb. This would of course be much more worrying. Thus, when communicating the Glasgow Coma Scale score of a patient, who does not score 15 on the scale, each domain score must be made explicitly clear.

SOME COMMON QUESTIONS

SLIDE 27

When should the Glasgow Coma Scale be measured and how often?

It is always helpful to have a measurement done of Glasgow Coma Scale score, when the patient is first clinically encountered. This allows clinicians to have a baseline to which any subsequent deviations can be compared. The frequency of measurement depends on the nature and severity of the clinical state of the patient, but initially if a patient is admitted to the emergency department, more frequent observations should be advisable, and the frequency could then be reduced, if the patient remains clinically stable.

If there has been any change in management of the patient, for example, if they have been given a strong medication, or if there has been operative intervention, the score should always be recorded following this, in order to pick up any benefits, or detrimental effects of that particular treatment.

SLIDE 28

What if a patient cannot demonstrate eye opening due to, for example, bilateral facial fractures?

If the swelling from these fractures obscures the orbit to such an extent so that the patient cannot demonstrate eye opening effectively, then this is recorded on the observation chart as a **'C'** in the 'No response' section of the Eye domain.

SLIDE 29

What if a patient cannot demonstrate a verbal response, due to for example, a tracheostomy tube or trauma to the upper airway?

If this is the case, then a **'T'** should be recorded in the 'No response section' of the Verbal domain. Similarly, if a patient is dysphasic, the verbal response might be difficult to accurately assess. Under these circumstances, you record a **'D'** in the 'No response section' of the Verbal domain.

SLIDE 30

What if a patient scores better in the motor domain on one side of the body, compared to the other? For example, a hemiplegic patient might only be able to obey commands or localize to pain, with the side of the body that is not paralyzed. Under these circumstances, we record the BEST motor response, that is, whichever side scores higher according to the motor component of the scale. Furthermore, repeated stimulation of motor response, for example by eliciting pain, may sometimes heighten and better the response, in which case the best, or highest scoring response should be recorded. In the case where a patient scores lower on one side, this is of course also important clinical information about a focal lesion of the brain, but should be recorded as part of the overall neurological examination, and not as part of the Glasgow Coma Scale score.

SLIDE 31

How do we best assess pain? There are many different ways used within clinical practice to elicit pain to patients. However, whichever way is used, it is important to

a) elicit enough pain to allow the patient to respond adequately,

b) not elicit too much pain, and

c) allow a localizing response to be recorded.

Firstly, in order to see whether a patient will eye open to pain at all, apply **pressure to the nailbed** of one of the patient's fingers. This can be done using e.g. a pen. If this is unsuccessful, or the patient does not eye open to pain, move onto assess for localizing stimuli. I would recommend using pressure on what is called the supra-orbital ridge. Have a feel of your own – slide your finger along the upper lip of your orbit until you feel a ridge. Now press there. **Supra-orbital ridge pressure** is ideal, as it allows for a true localizing response to be elicited, and exerts just enough pain to be significant to stimulate a motor response, but not enough to cause any harm or injury to the patient. If applying supraorbital ridge pressure is not possible for whatever reason (e.g. in patients with extensive facial injuries), then I would recommend **pinching the patient's earlobe**. This also allows a localizing response.

FINALWORDS

SLIDE 32

If a certain domain of the scale cannot be assessed (for example the voice portion in a tracheostomy patient), then this is not a problem. The other domains can be assessed and reported separately instead. However, the system fails completely, when the component scores are simply summated into a total score.

SLIDE 33

Accurate assessment of the Glasgow Coma Scale Score allows us to get a score that very strongly correlates with outcome and complications. The lower the score, the greater the likelihood of extra-cranial complications, including hypoxia and hypotension, and intra-cranial complications, such as hematoma, and of other parameters, such as intracranial pressure and cerebral metabolism.

SLIDE 34

Generally, a total **GCS of less than 8** is accepted as an operational definition of **coma**. However, as mentioned above, it is important to **communicate** the individual components of the score. So, when presenting the patient on rounds, or making a referral to neurosurgery – say what you see. So to re-iterate, or example, rather than just saying, 'this patient has a GCS of 10', say: 'I have examined this patient. He is localizing to pain, uttering incomprehensible speech, and only eye opening to painful stimuli'. This allows clear communication.

SLIDE 35

I hope this video has been useful and enjoyable. As mentioned before, the key to proficiency with using the Glasgow Coma Scale is to examine many patients, and take every opportunity to present it. When Professors Teasdale and Jennett developed the scale, the whole point was to make something that was very complex much more simple, and if used correctly, the Glasgow Coma Scale is one of the most useful instruments we have in medicine and surgery.

Thank you.

INTRACRANIAL HEMORRHAGE

INTRODUCTION

SLIDE 1

In this video, I am going to talk about the four common types of **intracranial hematoma or hemorrhage** that we deal with in clinical practice. Being able to understand the underlying mechanism of how these hematomas are formed, whether through trauma or spontaneously, and their subsequent management and prognosis, is of uttermost importance to anyone who works in clinical practice. Intracranial hematoma is such a major cause of morbidity and mortality, so I hope this video will provide you with the basics to confidently distinguish between the different types. However, it should be noted that in real life, the clinical syndromes of the different types may not be so easy to delineate. Indeed, a patient who is brought to the emergency department with a hemiplegia and depressed level of consciousness may have acquired any one of the four different types, and so we rely very heavily on imaging and other tests, in order to be able to institute the right management plan. The management options presented in this video are those suggested, when intervention is indicated. As with treating any medical or surgical condition, the management of the hematomas must be tailored to the patient's comorbidities, overall life expectancy, and of course the severity of the clinical picture. Conservative management may be indicated for one patient, and surgical intervention in another.

SLIDE 2

Intracranial hemorrhage or hematoma is a generic term that describes the pathological accumulation of blood with the cranial vault. As we know, the cranial vault contains a variety of structures, including the brain, its associated ventricles, and the meninges, and so the hematoma can occur within, or be associated with any of these structures, i.e. in the brain parenchyma, ventricles, or in the meningeal spaces.

THE BASIC STRUCTURE OF THE CRANIUM AND ITS CONTENTS

SLIDE 3

Before we start talking about the four particular types of hematoma in detail, let's have a look at the basic structure of what is contained within the cranial vault.

SLIDE 4

If we open up the scalp and cranium, we see a white glossy membrane. This is the dura mater, which contains two layers, the outer and the inner layer. Surrounding this rather tough membrane is a number of meningeal arteries that, as the name implies, supply the meninges with blood. If these bleed for whatever reason, blood collects between the skull and on top of, or outside of, this membrane and forms what we call an **extradural** or **epidural hematoma**. As you know, *extra*- is Latin for outside, and *epi*- is Latin for on top of, both referring to the relation to the dura mater. Both of these terms are used in clinical practice, and which one you use will sometimes depend on where you practice. Both are fine however, and pick whichever term you prefer, but make sure you are consistent.

SLIDE 5

If we then move further down, beneath the dura mater, we reach another membrane – the so called arachnoid mater or membrane. The space that is formed between the dura mater and the arachnoid membrane is called the subdural space – *sub*-, obviously meaning under in Latin, referring to the relation to the dura mater. In the subdural space, we find numerous bridging veins. Throughout most of the skull, the dura mater and arachnoid mater are very close to each other, but sometimes they separate forming larger spaces, called dural venous sinuses. If a hemorrhage occurs from one or many of the bridging veins, due to trauma for example, blood will collect in the subdural space, forming a **subdural hematoma**.

SLIDE 6

The next type of hematoma occurs if we go beneath the arachnoid membrane. The word arachnoid is taken from the Latin word for spider, because of the fine spider-web like appearance of the very thin fibres of the arachnoid membrane, which extend to attach to the next membrane, which find beneath the arachnoid membrane, the so called pia mater. A space is formed between these two membranes, where these spider-web-like fibres travel, and we call this the subarachnoid space, referring to underneath the arachnoid membrane. The arachnoid membrane and the pia mater are very closely associated all the way down to spinal level S2, where they fuse together to form the so called filum terminale – and so the subarachnoid space extends all the way from the cranium down to the lower spine. In association with this space are a number of blood vessels which can bleed both as a result of trauma and spontaneously, and this will cause blood to disseminate throughout the arachnoid space, forming a **subarachnoid hemorrhage**. But more on this later…

SLIDE 7

Finally, if we then go below the pia mater, we reach the brain. All the hemorrhages we have spoken about so far occur in spaces within the cranial vault, but outside of the brain. However, as the brain contains so many blood vessels, hematomas can of course occur within the brain parenchyma. If they do, they are called **intracerebral hematomas**. This is a very generic term describing any bleed in the brain tissue and different areas of the brain. For example, these bleeds can occur within the basal ganglia, cerebellum, brain stem, or cerebral cortices. As you can imagine, although the different types of intracerebral bleeds share some clinical features, the location of the bleed will cause some very specific clinical features, and knowing these will be very helpful to guide you as a clinician, to diagnose the patient prior to having access to any kind of neuro-imaging.

SLIDE 8

Right. So now that we know where the different types of hematomas are broadly located. Let's proceed to talk a little a bit about each of the types how they occur, what causes them, how we treat them, and what the prognosis is. Using the model of imaging the skull as a globe with various different layers, separated by membranes, where hematomas occur between these layers, let's start with the hematoma that occurs in the outermost layer, between the calvarium/skull and dura mater – the epidural hematoma.

EPIDURAL HEMATOMAS

SLIDE 9

Imagine a scenario; John, 7, is outdoors playing baseball with his grandfather. His father hits the ball, and it hits John on the temple area of his skull. John immediately loses consciousness, his father runs up to him, starts shaking him, with no response. 30 seconds later, John regains consciousness, complaining only of a mild headache for the rest of the afternoon. Later in the evening, John's mother wakes up hearing a bang coming from John's bedroom. She quickly runs to his room, and finds him collapsed on the floor, completely lifeless.

SLIDE 10

He is rushed to hospital. On arrival to the Emergency Department, he is unconscious, and has right-sided hemiparesis, and left-sided pupillary dilatation.

SLIDE 11

A CAT scan of John's head is performed, and the diagnosis is made: he has a large left-sided epidural hematoma.

SLIDE 12

What has been described to you is the typical, textbook scenario of how an **epidural hematoma** occurs, and how it presents. We saw a brief posttraumatic loss of consciousness following John being hit by the ball, we then saw what is called a 'lucid interval' (which basically means fully conscious) for several hours, which was then followed by obtundation, or loss of consciousness. While only about 10% to 25% of patients present like this, it is useful to remember this story. Males are four times more likely to get these types of bleeds, they mostly occur in younger people (between the ages of 2 and 60), and most bleeds are traumatic and result in arterial bleeding (which is why we see the relatively quick deterioration), as opposed to some of the other hematomas, which will speak about, that are normally venous in nature.

So let's talk about the event that occurred.

SLIDE 13

As the ball hit John's temple area of his skull, it fractured his skull, giving him a tempo-parietal skull fracture. As it did this, the fracture caused the dura to be stripped from the skull, to which it is normally adherent, causing laceration of blood vessels. Given his presentation, this was most likely an arterial bleed, and the culprit most likely the middle meningeal artery, which exits its bony groove right at the pterion where the ball hit John, making it very vulnerable to these types of injuries. Once the artery started to bleed, it did so into the space that was created, when the dura was stripped from the skull following the fracture. This traumatic event immediately caused John to loss consciousness, due to its pure concussive effect. However, due to the body's ability to compensate the rise in intracranial pressure caused by the bleed, John regained consciousness again. Exactly how the body is able to compensate was until recently rather poorly understood, but studies have indicated that this may be due to venous shunting of the bleeding. However, eventually, the body cannot compensate anymore through these mechanisms, and the intracranial pressure rises to such an extent, where the patient becomes unconscious and neurologically compromised again, and is at severe risk of developing neurological damage.

SLIDE 14

However, not all epidural hematomas present like this. Some do not have a lucid interval, and certainly, some are not due to arterial bleeding (although 85% are), and some do not occur over the lateral aspect of the skull. In fact, the bleeding may be venous in nature, coming from the middle meningeal vein, or one of the dural venous sinuses that I mentioned previously. Although it may be dangerous and risky to try to clinically distinguish between arterial and venous epidural hematomas, deterioration is often slower if the bleed is venous, as venous blood pressure is obviously significantly lower than arterial blood pressure. 70% of these hematomas occur on the lateral aspect of the cerebral hemispheres, with their epicenter at the pterion, but the other 30% may occur in the frontal or occipital aspect of the brain, or in the posterior fossa.

SLIDE 15

The symptoms associated with epidural hematomas include some of those we saw in John:

- **Loss of consciousness** due to rise in intracranial pressure is ultimately seen in most patients, but up to 60% of patients may not have the initial, brief period of loss of consciousness that we saw in John. Conversely, some patients will lose consciousness but not exhibit the lucid interval seen in John. This occurs in about 20% of patients.
- **Hemiparesis.** In John's case, we saw a contralateral hemiparesis, which is the most common, especially in lesions that are on the lateral aspect of the cerebral hemispheres. However, in lesions that are not lateral, we may sometimes get an ipsilateral hemiparesis, as the lesion may shift the brain stem away from it, causing compression of the cerebral peduncle on the tentorial notch on the opposite side, causing an ipsilateral hemiparesis. This is what is called a 'false localizing sign', and the name is on the tin: it may trick the clinician into thinking the lesion is on the opposite side of the neurological manifestation. This is why getting adequate neuro-imaging prior to intervention is essential.
- **Pupillary dilation**. About 60% of patients will have compression of the optic nerve (cranial nerve III), which will cause a palsy of this nerve, resulting in dilatation of the pupil. In about 85% of these patients, this is ipsilateral.

SLIDE 16

- Other manifestations that we see in patients with epidural hematomas include **headaches, vomiting, seizures, hyper-reflexia**, **the Babinski sign**, and **elevated CSF pressure**. In addition, in young pediatric patients, we might see a **drop in hematocrit**, essentially the concentration of the blood, due to the sheer volume of blood loss caused by bleeding from the lacerated blood vessel.

SLIDE 17

Right, so John comes into the ED, you examine him and find that he is neurologically compromised in some way. This, along with his history, will lead you to want to order a few tests and investigations. So what do you do?

SLIDE 18

Well, in about 60% of cases of epidural hematomas, plain **skull-X-rays** will identify a fracture. Consequently, the X-rays will <u>not</u> identify the fracture in 40% of cases. So obviously, modern day clinical practice uses more sophisticated imaging – namely **CT scanning.**

SLIDE 19

A patient who has a suspected head injury, and especially if it is a life-threatening one, should have an urgent CT scan performed. So what would we expect to see in a patient like John?

Well, in more than 80% of cases, there is a very characteristic appearance. The lesion is pretty obvious, and is sort of lens-shaped. In neuro-radiology speak, we call this a <u>high-density, biconvex or lenticular lesion</u>, which literally means lens-shaped. And as you can see, the lesion is right adjacent to the skull. However, notably, in some cases the lesion may be lenticular against the skull, and straight against the brain. Confusingly, in a small proportion of cases, the lesion might actually have this more crescent shaped appearance, which normally would be more associated with another type of hematoma, which we will talk about in a few minutes, namely the subdural hematoma. This obviously reinforces the fact, that even if we have all the imaging in the world at our disposal, a thorough <u>clinical history and examination is always essential</u> in order to really be sure of what diagnosis we are dealing with.

SLIDE 20

As you can see in this image, there is a structure; a large, crescent-shaped fold of meningeal layer of dura mater that descends vertically in the longitudinal fissure between the cerebral hemispheres. This is the *falx cerebri*, which is important to know about in the context of cerebral hematomas. An extradural hematoma may actually cross this falx, but is often limited by the skull sutures, where a subdural hematoma would not cross the falx. Due to the, so called, **mass effect** (i.e. pressure caused by the hematoma) which is frequent with subdural hematomas, there might be shift of this midline. This is a serious sign. As you can see, EDHs normally have uniform density, sharply defined edges, and high attenuation (which is due to essentially undiluted blood). Sometimes the hematoma may have the same density as the brain, which is why IV contrast may be necessary in order to really rule in or out an epidural hematoma.

SLIDE 21

Overall mortality of EDHs is high – between 20-55%, but optimal diagnosis and treatment will get this down to about 10-12%. Interestingly, if there is no lucid interval, there is a worse prognosis – about double of that with a lucid interval. Why do patients die?

SLIDE 22

In the majority of cases, it is because of the pressure caused by the lesion, leading to herniation of a structure called the uncus, and pressure, which causes injury to the midbrain, and subsequent respiratory arrest. Please also note, that 20% of patients with an EDH on CT will also have an acute subdural hematoma on CT, which worsens the prognosis significantly.

Also note, that in some cases, the first CT scan will not show an EDH and the presentation might be delayed. Always have a high index of suspicion in someone with a clinical history like John's, and who is exhibiting neurological impairment.

As you can see, urgent treatment of these lesions is necessary. So how do we do it?

SLIDE 23

As you learn in medical school, pretty much any medical or surgical condition can be managed conservatively, medically, or surgically.

SLIDE 24

However, the vast majority of extradural hematomas are managed surgically, due to the high risk of rapid deterioration. If the hematoma is very small (less than 1 cm), neurological signs are absent, and there is no evidence of herniation, the patient can be admitted, closely observed and sometimes given steroids, which helps to contain the size of the lesion. Follow-up scans should be performed. However, these patients can deteriorate very quickly.

Surgical treatment has a much larger role, especially in pediatric patients, where there is much less room for the hematoma to expand without causing neurological injury.

Slide 25

The details of how we perform the surgery are not really necessary, but plainly speaking; we would perform a **craniotomy and evacuate** the clot. A craniotomy means that we in fact remove a skull flap, rather than just doing **burr holes** as we see in a subdural hematoma. This is because with epidural hematomas, it is important to visually see all of the hematoma and craniotomy allows for more complete evacuation.

SLIDE 26

Surgery has three main goals:

1. **Removal of the hematoma** which will lower the intracranial pressure and eliminate the focal mass effect.

2. **Surgery** will allow us to achieve haemostasis – i.e. stop the bleeding. We do this by coagulating any bleeding soft tissue coming from dural veins or arteries, and applying bone wax to any bleeding vessels associated with fractured bone (for example the middle meningeal artery). The large view we get from the craniotomy is also important here.
3. Finally, it allows us to institute measures to **prevent re-accumulation of blood** which may occur, and we do this by stitching up the edges of the craniotomy and dura, and use a central tenting suture.

SUBDURAL HEMATOMAS – CSDH AND ASDH

SLIDE 27

Right, so having spoken about EDH, let's move onto EDH's cousin, the subdural hematoma.

SLIDE 28

As mentioned before, these occur underneath the dura.

SLIDE 29

Firstly, these are divided into **acute subdural hematomas** and **chronic subdural hematomas**, which are actually rather different in terms prognosis. In fact, acute subdural hematomas which also occur traumatically, imply an even higher level of impact damage (i.e. level of trauma) than epidural hematomas – to get that far into the brain, you'd have to hit your head very badly. There is often severe underlying damage to the brain on presentation, which may be less common with epidural hematomas, and certainly much less common with chronic subdural hematomas.

SLIDE 30

Right, so what are the common causes of acute subdural hematomas? Well firstly, severe impact trauma, like a car accident, may cause damage to the brain parenchyma. This will cause bleeding from the blood vessels associated with the brain parenchyma, and accumulation, usually around the frontal or temporal lobe. Focal signs tend to develop later than with EDHs, and be vaguer. As I said, these injuries usually imply severe underlying primary brain injury. The second mechanism for this injury, also following trauma, may be from so called acceleration-deceleration injuries which occur during aggressive head motion, tearing surface or bridging blood vessels in the brain, also for example following a car crash. Here primary brain injury may be less severe, but rapid deterioration often occurs. Interestingly, ASDH may occur with a history of minor trauma, or without a history of trauma, in patients on anti-coagulation therapy. Males on anti-coagulation therapy have a 7-fold higher risk of this, and females a whopping 26-fold higher risk. So be cautious!

SLIDE 31

So let's talk about some **imaging**. But before we do, have a look at this table. As you know, the way blood in the brain looks on a scan will change over time, in terms of **density**, which is useful clinically to distinguish between acute, subacute, and chronic subdural hematomas. For acute bleeds, which are defined as having occurred within the last 1-3 days, we expect the lesion to be hyperdense on CT scan, i.e. of a higher density – it looks more white than the brain tissue. Subacute bleeds, which are defined as having occurred within between 4 days to 3 weeks of the injury, are isodense, that is, the same density as the brain parenchyma. Chronic hematomas, which are defined as having occurred more than 3 weeks ago, are hypodense with a similar density to CSF, for example. Very old hematomas, may even change shape and look like epidural hematomas with their lenticular shape, and again start becoming denser, but still of less density than seen with ASDHs or EDHs, for example.

SLIDE 32

Right, so **ASDHs** specifically. What do we see? Well firstly, because of the way subdural hematomas occur, the shape of a subdural hematoma is different to that of an epidural hematoma. Instead of being shaped like a lens, it is **crescenteric**. We sometimes see a lot of swelling or edema of the surrounding brain parenchyma, and after about 4 days or so, membranes start forming around the actual hematoma. However, as I alluded to before, after sometime the lesion becomes of more or less the same intensity as the brain parenchyma, and we might not be able to confidently point out the hematoma. Clues to look for here are things like **obliteration of the sulci** (or folds) of the brain parenchyma or **midline shift** (which of course may not be present, if the patient is unlucky enough to have bilateral subdural hematomas). Eventually, the bleed gets darker than the brain parenchyma, and it becomes a chronic subdural hematoma. In the acute stage, subdural hematomas are normally less dense than epidural hematomas (because of the mixing of blood and CSF) and more diffuse, less sharply demarcated and concave over the brain surface. So how do we treat acute subdural hematomas?

SLIDE 33

Well there are specific guidelines for this, but at your stage, the details are not necessary. In addition to the patient's clinical and neurological condition of course, general consideration that would affect decision making for surgery would be:

- If the patient is on **anticoagulation**. If the patient is clinically stable, **reversing** these may help to increase the safety of surgery.
- The **location** of the hematoma and level of **midline shift**
- The patient's **baseline level of function**

SLIDE 34

Acute subdural hematomas are treated surgically in a very similar way to epidural hematomas – most commonly through a **craniotomy**, allowing good surgical access, as opposed to burr hole drainage, which is mainly used when we are dealing with chronic subdural hematomas.

SLIDE 35

Even after surgical intervention, mortality of acute subdural hematomas is significant – mainly because of the often severe underlying brain injury, rather than the actual subdural hematoma itself.

If you ever visit the neurosurgery department, you may hear doctors mentioning the 'four hour rule' in the context of acute subdural hematomas. Again, unless you decide to specialize in neurosurgery, the exact details of this are not necessary. However, essentially, this rule dictates that patients who are operated on within 4 hours of acquiring the acute subdural hematoma, have a much, much higher chance of survival and better functional outcomes.

SLIDE 36

There are a few other types of acute subdural hematoma to mention, such as delayed acute subdural hematoma and infantile acute subdural hematoma. However, these will not be covered in this video. Shoot me an Email if you want a summary of these.

SLIDE 37

Moving on swiftly to chronic subdural hematomas then. As mentioned previously, chronic subdural hematomas are defined by how they occur, and the chronicity. Compared to acute subdural hematomas, the mechanism and patient population is rather different.

SLIDE 38

Chronic subdural hematomas occur mainly in the elderly, and the average age of the patients is in the 60s. **Trauma** may be identified in about half of cases, but can often be very trivial. Other risk factors include **alcohol abuse**, **seizures**, and **coagulopathies**, or indeed, being on **anti-coagulation treatment**. Furthermore, CSDHs are often bilateral – in up to about a quarter of cases. In elderly patients, these hematomas can in fact be very large without major compromise, as elderly people's brains shrink, thus increasing the subdural space.

SLIDE 39

Of course, many CSDHs probably start off as ASDHs, and the subsequent inflammatory response to the presence of blood within the subdural space, causing the appearance on imaging. When a clot forms, fibroblasts converge onto the clot forming membranes all over its surface, and the growth of capillaries.

So how do patients with chronic subdural hematomas present to us?

SLIDE 40

Well, consider a typical patient. 87 year old Margaret falls over in the nursing home and hits her head. There is only slightly bruising to her forehead, and no loss of consciousness, at the time. However, later that week, Margaret becomes increasingly confused and complains of a headache. One morning, when her daughter comes into the room to wake her up, she is very drowsy, and therefore brought to hospital.

SLIDE 41

She has a CT scan of her head, and bilateral CSDHs are diagnosed.

SLIDE 42

And this is what we see in the vast majority of patients with CSDH. Patients present with minor symptoms of headache, confusion and language difficulties. In addition, as would be expected from a space-occupying lesion in the head, patients may also develop coma, hemiplegia and various types of seizures. However, sometimes patients may have very little or no symptom, and we first find out about the CSDH when they have a CT scan.

SLIDE 43

So how do we treat these then? Well, as mentioned before with the other types of bleeds, there is a role for conservative/medical and surgical treatment, which we will tailor depending on the patient and clinical severity.

Firstly, some of these patients are very prone to seizures, and so **early seizure prophylaxis** with something like phenytoin may be advisable. However, whether this is used or not differs between different clinicians. Secondly, as many of these patients are on **anticoagulation** (like warfarin for example), this should **be reversed**. If the patient happens to be on anticoagulation for a metallic heart valve for example, then this should obviously be done whilst liaising with the local hematology service.

If the patients are symptomatic, and/or the hematoma is thick (more than 1 cm), then **surgical treatment** is indicated.

SLIDE 44

The specifics of the surgical procedures used are not necessary, but these are generally treated with various **burrhole procedures**, allowing the clot to be removed. In some cases, for example with recurrence, a **craniotomy** may be performed, with the bigger incision allowing the surgeon to remove the membranes around the clot more fully. After the procedure, we generally leave a **subdural drain** in situ, to prevent recurrence. This drain is kept in for about 24-48 hours, then removed with a **follow-up CT** performed after to establish a baseline in case the patient deteriorates later on.

SLIDE 45

Most patients with a good baseline prior to the CSDH do rather well after surgical decompression, and the mortality rate for CSDH with surgical treatment has been shown to be between 0-8% in studies.

SLIDE 46

Right, so we have spoken about epidural hematomas, and subdural hematomas. Next, we will talk about another type of hemorrhage that we see a lot in the neurosurgical unit, and which is associated with a significant mortality and morbidity, often in relatively young patients.

SLIDE 47

Subarachnoid hemorrhage means that there has been a bleed in the subarachnoid space for any reason – that is, the area between the arachnoid membrane and the pia mater.

SLIDE 48

When someone says subarachnoid hemorrhage, you probably think – a burst aneurysm. And whilst this is an important cause of subarachnoid hemorrhage, the most common cause of subarachnoid hemorrhage is actually trauma. Think about a patient who has been in a severe car accident with polytrauma, and you get the right idea.

SLIDE 49

So as with all the types of hematomas or hemorrhages, there are traumatic causes and spontaneous causes. And whilst the initial management and management of complications may be similar in all types, definitive management will depend on the cause.

SLIDE 50

Right, so what are the **spontaneous** causes of subarachnoid hemorrhage? Well, if you think a burst or leaking aneurysm within the circle of Willis for example, then you are right. The pathophysiology and specific treatment options for cerebral aneurysms are well beyond the scope of this video, but some basic knowledge is helpful. Ruptured intracranial aneurysms account for between 75-80% of all spontaneous subarachnoid bleeds. The next most common cause is much more rare – so called **Arterio-Venous, or AV-, malformations**, which account for around 4-5% of subarachnoid bleeds. The specifics of them are not really necessary here, but they are essentially when arteries are abnormally connected directly to the veins, bypassing the norm of having capillaries in between the both.

SLIDE 51

Other rare causes that are important to be aware of include **vasculitides**, **tumors, cerebral artery dissection, coagulation disorders,** and **certain drugs** (like **cocaine**). The incidence of subarachnoid hemorrhage due to cerebral aneurysms is about 6-8 per 100,000 population in the Western world.

SLIDE 52

Subarachnoid hemorrhage is a severe condition, and outcomes are often poor. In fact, 10-15% of patients die before they even reach hospital, which is more than for most medical or surgical conditions. And within the group who do survive the initial event, about 10% die within the first few days. After 30-days, 50% of the patients, who are still alive, will be dead.

SLIDE 53

So who gets subarachnoid hemorrhages? The peak age of these types of bleeds is from the mid 50s to 60 years of age, and about 20% of cases occur in young people, from ages 15 up to 45. About a third of these patients develop them during sleep, and only about half of patients have any kind of warning symptoms (e.g. headaches), prior to the hemorrhagic event.

SLIDE 54

As with any type of hemorrhage, there are certain **risk factors** for subarachnoid hemorrhage. These include **hypertension, oral contraceptives, substance misuse** (such as cocaine), **pregnancy,** and **certain conditions** that are also associated with an increased risk of cerebral aneurysms. Another cause which may be rare, but that I have witnessed myself, is that patients, who have aneurysms, have a lumbar puncture draining too much CSF – the back pressure here might cause the aneurysm to burst.

SLIDE 55

Right, so, what would be the typical presenting symptoms of subarachnoid hemorrhage? The classic, exam, type-answer for a cardinal symptom is the so called '**thunderclap headache'**. In fact, headaches are by far the most common symptom of subarachnoid hemorrhages – present in up to 97% of cases. Patients complain of a severe, sudden-onset headache: 'the worst headache of my life'. Some patient may not have any other symptoms than this, and we call this headache that acts as a warning of a subarachnoid bleed, a so called **sentinel headache**. In fact, although these headaches can be due to a bleed, they may also be due to aneurysmal enlargement, preceding an actual bleed. And yes, the most common symptoms we see would be that a patient presents with a **sudden onset, severe headache, vomiting, syncope**, and symptoms of **meningism** (caused by blood irritating the meninges), such as **neck pain** and **photophobia**. As expected with meningism, we see **nuchal rigidity**, and a **positive Kernig's** and **Brudzinski's sign**. Some patients also go into a **comatose state** due to various reasons, including increased intracranial pressure, actual damage to brain tissue due to intraparenchymal hemorrhage, hydrocephalus and seizures. Patients may also get various types of **intraocular hemorrhage –** the specifics are not necessary here, but these are all likely due to elevated CSF pressure which causes disruption of the retinal veins.

Some focal neurological symptoms – such as a so called '**surgical third nerve palsy',** may be present, caused by compression of the third cranial nerve by an aneurysm.

SLIDE 56

So what do we do to investigate patients who we think may have suffered a subarachnoid hemorrhage? Well we do tests to elucidate two things: firstly, we want to diagnose the actual SAH. Secondly, we want to identify the source of this SAH.

SLIDE 57

To diagnose the SAH, we do a **plain, non-contrast CT scan** of the head. In fact, a good-quality (with no motion artefact), high-resolution, non-contrast CT will detect SAH in more than 95% of cases, if performed within 48 hours of the hemorrhagic event. Often, we see blood (i.e. white) in the subarachnoid spaces, or in more subtle cases, blood in the occipital horns of the lateral ventricles, and parts of the Sylvian fissures.

SLIDE 58

We may also see increased ventricular size (indicative of hydrocephalus), a concomitant intracerebral hematoma, infarct and blood in the cisterns and fissures. Interestingly, the location of the blood on this CT scan can also help to predict the location of an aneurysm. However, the specifics for this are not necessary for the purpose of this video.

SLIDE 59

However, there is a small proportion of cases, where SAH is not detected on plain CT. And in these cases, when SAH is suspected, the most sensitive test for SAH, a **lumbar puncture**, should be performed. But once again, remember that this may actual precipitate bleeding from an aneurysm. What do we look for with this lumbar puncture then?

- Well, firstly, the **opening pressure** (i.e. a measure of the pressure of CSF within the ventricular system), will be **elevated**.
- The second, characteristic finding is so called **xanthochromia** of the CSF fluid that is drained. We essentially send of CSF to the lab, this is centrifuged, and spectrophotometry can detect the presence of heme pigments within the CSF, caused by the breakdown of the RBC that were released into the CSF as a consequence of the SAH. In fact, sometimes we can suspect this by just visually inspecting the CSF: it will have a yellowish discolouration. However, this may also be due to a traumatic tap, so serial tubes of CSF should be taken. Furthermore, there are some other things that cause false positives, such as jaundice or high protein content in the CSF, as a result of bacterial meningitis for example.

In addition to elevated opening pressure and xanthochromia, we may also see

- **high RBC content** in the CSF,
- **high protein content** in the CSF and as well as a
- **normal/reduced glucose content**.

SLIDE 60

MRI is not sensitive for SAH in the acute stage, but may be useful to detect subacute or remote SAH. Further tests we do along the line to evaluate the presence of an aneurysm and to detect something I will mention that is called vasospasm, include **MRA, CT angiograms,** and **digital subtraction angiograms**, where we can study the location of the aneurysm, detect vasospasm and assess any feeding arteries. If an aneurysm is found we will study various parameters that will determine the management approach (e.g. surgical clipping vs endovascular coiling). We are interested in knowing the size of the aneurysm, the size of the neck of the aneurysm (narrow necks are better for coiling whereas broader are not), and we are also interested in the ratio between these two.

We also use various grading systems to guide prognosis, but these are not necessary to know for the purpose of this module.

Right, so, onto the most important part of this: How do we manage these complex and often very ill patients.

SLIDE 61

Let's divide it into two stages: initial management of the acute event, and then definitive management.

Initial management has a few aims:

- Firstly, we want to prevent **re-bleeding**.
- Secondly, we are also worried about **hydrocephalus** due to either obstruction (blockage of CSF by blood clot) or because of toxic breakdown products causing dysfunction of the resabsorption of CSF.
- Thirdly, we are concerned about the possibility of **ischemia** due to vasospasm, and
- fourthly we also about **hyponatremia**.

It is important to early know the source of bleeding, by performing an early CT-angiogram.

SLIDE 62

When patients are admitted, they should be in a monitored ICU bed with frequent neurological observations and bed rest at 30 degrees and a strictly monitored fluid balance chart. In order to prevent cerebral salt wasting (i.e. losing large amounts of sodium in the urine), particular fluid regiments should be given according to protocol; normal saline and potassium for example. Anticonvulsants (such as levetiracitam), sedation as necessary, analgesics, stool softeners, antiemetics, and calcium channel blockers should be given, and the work-up must include routine bloods, arterial blood gases, and if available, trans-cranial Doppler US.

SLIDE 63

One of the main complications of SAH that you should know about, although not in details, is **vasospasm**. This is when the patient develops delayed ischaemia and/or cerebral artery narrowing as seen on angiography, following SAH. The main risky period for this to happen is between days 3-14 after the SAH-event. Generally, patients with worse SAH grade, or more blood on the CT following SAH, are at higher risk of this. This should be suspected in patients with a history of SAH who develop both non-specific symptoms (such as headache, lethargy, disorientation, meningismus), and more specific, stroke like syndromes, such as ACA syndrome, or MCA syndrome. How do we treat this dangerous condition? Well, we deal with the triple H's with so called **triple-H therapy**, including hypertension, hypervolaemia, and haemodilution, as well as possible direct **vasodilation** of the artery undergoing vasospasm by using a stent or injecting intraarterial verapamil, or another calcium channel blocker.

CONCLUSION

SLIDE 64

Right. So in this video we have discussed three major types of hemorrhage or hematoma: Epidural hematoma, subdural hematoma and subarachnoid hemorrhage. As you have noted, they all tend to occur in somewhat different patient groups, with somewhat different symptoms, and somewhat different prognoses. In addition to these, there are intracerebral hematomas, which have not been covered in this video, but may come up in later videos.

The point of this video is not to make you experts in detail of all of these different types of hematoma. As most of you will not go into neurosurgery practice (if you do, you'll certainly learn more about these in detail), the point is to give you – as future clinicians on the ground – some kind of intellectual framework to enable you to more effectively diagnose and distinguish between the different types of bleeds. However, as a final note, real life is of course never as simple as theory. A lot of these bleeds may present in overlapping ways. The history is not always as clear-cut, for example, of a boy being hit with a baseball hat on the temple area of his cranium, causing an epidural. Just remember, **a careful history,** and **basic investigations** (which are much the same for all types of bleeds) are key wherever and whenever you work in medicine and surgery. And as always, if you are ever unsure of what to do next, a **neurosurgical consult** is always a mere phone call away.

SLIDE 65 TO FINISH

HYDROCEPHALUS

SLIDE 1

INTRODUCTION

In this video, we are going to talk about **hydrocephalus**.

SLIDE 2

Hydrocephalus – literally meaning 'water head' (which of course is not accurate, as CSF is what we have in our heads rather than water), is a word that you will find is mentioned often by neurosurgeons and neurologists. The reason for this is pretty obvious – it is associated with so many various types of neurosurgical and neurological pathologies, whether we are talking about brain tumors or brain bleeds. In fact, it is so important to know about, that it even deserves its very own concept video for you guys to enjoy.

SLIDE 3

CSF

At the heart of hydrocephalus is the fluid that is responsible for causing this pathology – namely **cerebrospinal fluid**. So, before we jump into the actual pathophysiology, diagnosis, and treatment of the different types of hydrocephalus, let's have a look at how cerebrospinal fluid is produced and circles around the central nervous system.

Cerebrospinal fluid or CSF, is a normally clear and colourless fluid, and surrounds the CNS. There are many proposed functions that CSF serves – including a shock absorbing function and mechanical support for the brain, an unspecific sink function for waste products from the brain, an important role in brain interstitial fluid homeostasis, as well as an immunological function, similar to what the lymphatic system does in the rest of the body.

SLIDE 4

It circulates from the lateral ventricles, through the interventricular foramina (Monroi) into the third ventricle, through the aqueductus Sylvii into the fourth ventricle, through the median foramen Magendii and the lateral foramina Luschkae into the cisterna Magna and the subarachnoid space, which is between the subarachnoid membrane and the pia mater. The CSF spends its time in the ventricles of the brain and the central canal of the spinal cord (small part), and the flow takes it through the foramen magnum down to about S2 spinal level, but the major part of CSF is directed over the hemispheres in the subarachnoid space. So it is a big space!

SLIDE 5

A major proportion of CSF is produced by active secretion involving different enzymes, e.g. carbonic anhydrase and Na+-K+- ATPase , in the **choroid plexuses –** which we find here, in the lateral ventricles, the roof of the third ventricle, and in the fourth ventricles. The remaining part of the CSF production occurs from the interstitial space, and possibly a small part from the ependymal cells. In adults, 0.3 mls of CSF are produced every hour, which equates to about 450 mls a day – which in practical means that the whole stock of CSF is replaced three times within a 24-hour period. CSF production is normally completely independent of things like intracranial pressure, except when intracranial pressure is so high so it impedes cerebral blood flow, and thus, indirectly, CSF production. CSF absorption into the blood stream is carried out primarily in the superior sagittal sinus by these little outgrowths, called **arachnoid villi** or **granulations**, that extend into the venous sinuses. Some drainage also occurs through the lymphatics and the choroid plexuses, and the rate of absorption depends on the pressure of CSF.

SLIDE 6

So what is CSF made up of? Well, in normal CSF, we expect to find various types of **cells** as well as **glucose** and **electrolytes**. In adult CSF, we don't expect to find very many lymphocytes – about 0-5 lymphocytes per cubic millimetre, and definitely no polymorphonucleocytes (such as neutrophils) or red blood cells. Sometimes, after a subarachnoid hemorrhage for example, i.e. when there is blood in the subarachnoid space, or after a traumatic lumbar puncture, we may expect to have an elevated white cell count as well, but anything over 10 WBC (white blood count) per cubic millimeter is abnormal. In addition to some cells, the CSF contains some solutes. The osmolarity of CSF is the same as that of plasma, and we find the same solutes: sodium, potassium, chloride, calcium, but the composition of solutes is different and the pH is slightly more acidic.

But enough about this. The take home message thus far is basically that a lot of CSF is produced every day, is regulated by production and absorption, travels all the way around the CSF and is important for shock absorption and as serving an immunological transporting function. So let's move onto where the star of the show, where things go wrong, and where the normally physiological role of CSF turns into a pathological one.

HYDROCEPHALUS – THE DIFFERENT TYPES

SLIDE 7

Hydrocephalus in general, including all the subtypes, has a prevalence of 1-1.5% in the overall population. As you can understand, in a system that depends on flow and production, many things can go wrong and things can get quite complex to conceptualize. However, things are made helpful by the way we classify hydrocephalus namely: obstructive hydrocephalus and non-obstructive (or communicating hydrocephalus) (in addition to a few rare types, which I won't mention here).

SLIDE 8

- **Obstructive hydrocephalus**, as the name implies, is when hydrocephalus is caused by a blockage anywhere here that is proximal to, or before absorption by, the arachnoid villi that I mentioned before. So if we were to scan the head of a patient with obstructive hydrocephalus, we would expect to see **enlargement of the ventricles proximal to the blockage**. So for example, if the obstruction was all the way down in the little canal called the aqueduct of sylvius, we'd see enlargement of the third ventricle, and lateral ventricles way out of proportion to the fourth ventricle.

SLIDE 9

- Conversely, when hydrocephalus is caused by **blockage at the level of the arachnoid villi** (i.e. due to worse absorption from the arachnoid villi), we call this **non-obstructive or communicating hydrocephalus**.

SLIDE 10

- Another useful way of dividing up the causes of **hydrocephalus** (which are many) is to think of the causes in terms of **congenita**l causes and **acquired** causes.
- Also note: first we will talk about the types of **hydrocephalus** that are caused by **increased intracranial pressure**. There is also a type of hydrocephalus in which there is actually **normal pressure**. But rest assured, I will make a note of this at the end of the video.

CAUSES OF HYDROCEPHALUS

Right, so let's talk about the **congenital** and **acquired causes** of **hydrocephalus WITH raised intracranial pressure**.

SLIDE 11

Some of the common **congenital causes** include the so called **Chiari malformations** (of which there are a two types), which essentially are a malformation of the cerebellum, which displaces the cerebellar tonsils through the foramen magnum (where you remember CSF has to flow), causing an obstructive hydrocephalus.

SLIDE 12

The **aqueduct of Sylvian**, which I also mentioned before as a vital path for CSF to flow, may be **stenosed**. In addition to these, there are some super-rare conditions that you do not need to know about.

SLIDE 13

Acquired causes include **infections**, which is the most common cause of **communicating, i.e. non-obstructive hydrocephalus**. Often this occurs post-meningitis, which can be due to either a purulent bacterial meningitis, or TB, for example, or here associated with an abscess (please note the catheter here).

SLIDE 14

The second most common cause of communicating hydrocephalus, is **post-hemorrhagic** hydrocephalus, that is hydrocephalus that occurs as a complication of an intracranial bleed. Note the blood here in the cisterns indicating a subarachnoid hemorrhage, as well as the widening here of the temporal horns of the lateral ventricles, indicating hydrocephalus. Commonly, this is due to a subarachnoid hemorrhage, but may also occur after an intraventricular hemorrhage. Sometimes this can be transient, but a rather big proportion of patients who have large IVHs will eventually develop a chronic type hydrocephalus.

SLIDE 15

Another common cause of acquired hydrocephalus, in this case **obstructive**, is **intracranial masses**. These include non-cancerous ones, such as **vascular malformations**, and **cancerous masses** causes blockage somewhere along the flow of CSF. Flow may also be blocked by **colloid cysts** at the foramen of Monroe, or even **pituitary tumors** that grow upwards. In addition, some kids get hydrocephalus after posterior fossa tumor removal. There are also some other rarer causes of acquired hydrocephalus, such as neurosarcoidosis or spinal tumors.

Just remember that there are some conditions which might **mimic** hydrocephalus. For example, **cerebral atrophy** may cause the ventricles to appear larger, and there are some weird and wonderful **developmental** abnormalities that cause larger ventricles that are not due to altered CSF dynamics.

So before we go onto the symptoms and signs of HCP, let's talk a little bit about of hydrocephalus looks like of a scan of the head – **CT head** is the preferred modality of choice, but hydrocephalus can obviously also seen on MRI. Acute hydrocephalus and chronic hydrocephalus may look somewhat different from each other. There are various criteria and ratios that we use, but these are not necessary for you guys. The gist is this:

SLIDE 16

Here are a few scans, showing hydrocephalus. Firstly, on this one it is very obvious with ballooning of the entire ventricular system. But some other things are useful to look for. On this scan, as you can see these things, the so called temporal horns of the lateral ventricles are enlarged, more than 2 mm. If someone does not have HCP, these should at most only be slightly visible, and in addition, the Sylvian, and interhemispheric fissures, are not visible. Furthermore, the frontal horns, again of the lateral ventricles, may have a ballooning appearance (making it look like Mickey Mouse ears), and the third ventricle may also be ballooned. Furthermore, perhaps more difficult to see, the areas surrounding the ventricles may have a lower density on CT than normal – so called 'periventricular low density'. We'll talk more about this when we review some other methods of detecting hydrocephalus.

Right, so how do these patients present? Well, this will depend much on the cause/etiology, whether we are considering kids or adults, as well as on whether the hydrocephalus is acute or chronic.

SLIDE 17

In **acute hydrocephalus**, for example, after a subarachnoid hemorrhage or because of a brain tumor, we would expect symptoms that are congruent with increased intracranial pressure. This includes

- a decreasing level of consciousness,
- papilliedema (which is swelling of the optic nerve),
- a headache,
- nausea & vomiting,
- gait changes,
- upgaze palsy (abducens nerve).

But please bear in mind that slowly enlarging ventricles may initially be asymptomatic. Then of course, for example, if a post-SAH patient starts complaining of these symptoms, **a CT head** should be performed, and this may then show the tell-tale signs of HCP that I mentioned before:

- enlargement of the dorsal and anterior horns of the lateral ventricles,
- obliteration of Sylvian and sagittal fissures, and
- periventricular low density.

If the hydrocephalus does not present as acutely, that is, it is chronic, then the presenting symptoms may be more insidious.

SLIDE 18

In children we see some specific things. As young children, we see that their cranium enlarges at a rate exceeding that of the face. This is noted on the **head circumference** and **growth charts** that are kept of young children. Before the fontanelles have closed (the last one, the anterior fontanelle, closes at about 18-24 months), these may bulge due to hydrocephalus. There is also something called the 'setting sun sign', which is an **upward gaze palsy**. Respiration may also be **apneic** and **scalp veins** may be **enlarged** and **engorged**, along with a few other specific symptons. Then, of course, non-specific symptoms such as **irritability** of the child.

In adults with **chronic HCP**, there are a few tell-tale signs of the CT head, such as a '**copper cranium'** and **empty sella**, but these are well beyond the scope of this video. Of course, these patients may also have the signs and symptoms I mentioned before of headaches, N&V etc.

TREATMENT OF HYDROCEPHALUS

So how do we treat these types of hydrocephalus?

SLIDE 19

Well, as you can imagine, the specific intervention differs somewhat upon the underlying pathology, the patient, and of course whether we are considering acute or chronic hydrocephalus. However, the surgical treatments that we use all aim to divert the flow of CSF, so less CSF stays within the ventricular system, thus acting to normalize intracranial pressure. So let me try to provide you with a useful overview. BUT, at least in terms of acute hydrocephalus, it is important to remember that some patient improve spontaneously, without intervention. For example, about half of the patients who develop HCP and impaired consciousness after SAH, improve spontaneously, without intervention. However, these patients can deteriorate quickly, and that is why often you will see clinicians erring on the side of caution of intervening.

SLIDE 20

HCP is definitely primarily a condition requiring **surgical treatment**, and the role of medical therapies remains elusive at best. Acetazolamide, a carbonic anhydrase inhibitor is sometimes used, and so is furosemide, a diuretic. However, the mainstay of treatment remains surgical.

SLIDE 21

In terms of surgical treatments, there are those that are temporary that can be performed at very short notice, even as soon as the patient is admitted in the emergency room, or more definitive options. Surgery aims to either **reduce** the amount of CSF in the system by directly removing it, or **diverting** it to elsewhere in the body, where it can be handled and disposed of. Please also remember: The goal of intervention is not to shrink the size of the ventricles to normal size, but rather to **optimize neurological function** and **prevent further deterioration**.

SLIDE 22

The first, and perhaps simplest way of removing CSF from the ventricular system, is through a **lumbar puncture** or LP. However, due to the **risk of causing tonsillar herniation**, this is only performed for communicating, or non-obstructive hydrocephalus. Lumbar punctures are perhaps particularly relevant after subarachnoid or intraventricular bleeds, where the hydrocephalus may only be transient until the bleed resolves. In these cases, serial lumbar puncture, for example one every 8 hours, may be a preferred therapy.

SLIDE 23

As a more semi-definitive procedure, we use an external ventricular drain. An **external ventricular drain** (**EVD**) (seen here), also known as a **ventriculostomy** or **extraventricular drain**, is a device used in neurosurgery to treat hydrocephalus and relieve elevated intracranial pressure when the normal flow of cerebrospinal fluid (CSF) inside the brain is obstructed. An EVD is a flexible plastic catheter placed by a neurosurgeon or neurointensivist, and managed by intensive care unit (ICU) physicians and nurses. The purpose of external ventricular drainage is to **divert fluid** from the ventricles of the brain and allow for **monitoring** of **intracranial pressure**. An EVD must be placed in a center with full neurosurgical capabilities, because immediate neurosurgical intervention can be needed if a complication of EVD placement, such as bleeding, is encountered. A twist-drill craniostomy is made at Kocher's point (an anatomical landmark 2-3 cm from midline, in mid-pupillary line) in the frontal bone and the catheter is inserted, with the tip placed in the third or lateral ventricles. A special type of drain allows us to regulate the hydrostatic pressure, which in turn allows us to set how much CSF we want to drain over a given time period, and the amount coming out of the drain should be recorded on a designated chart. However, as mentioned, an EVD is only a temporary measure, and for patients where the hydrocephalus remains **persistent**, more permanent, internalized measures are employed.

SLIDE 24

There are a few different options available (in addition to of course removing the cause, e.g. a brain tumor), but the most commonly used methods are through an **ETV** – which stands for Endoscopic Third Ventriculostomy, or through a type of **shunt**.

SLIDE 25

An **ETV** can be used for obstructive hydrocephalus, but is generally not used for communicating hydrocephalus. Details of the procedure are not necessary, but essentially during the procedure, an endoscope is inserted into the third ventricle, and a hole is made in the floor of the ventricle. This allows CSF to drain directly into the basal cisterns, rather than going the normal route, thus **bypassing the flow**.

SLIDE 26

A **shunt** is essentially a catheter with a valve on one end (the end that is in the ventricle),that drains into a body cavity or anatomical space. The most commonly used drain is a **ventriculo-peritoneal** shunt (or VP shunt), but there are **ventriculo-artial** shunts, **ventriculo-pleural** shunts, and others in any location where there is enough epithelial cell surface to allow absorption of CSF, and the particular type used will depend some on the preference of the surgeon, as well some practical considerations (e.g. if the abdomen is scarred from many previous abdominal operations, it might not be ideal). The proximal end of the catheter of the shunt can be placed in any of the ventricles or, in the case of the lumbar peritoneal shunt, in a space between the lumbar vertebrae. Some shunts are programmable, which allows us to set the rate of CSF drainage. Also remember that patients with shunts can present with symptoms of hydrocephalus – the symptoms we reviewed earlier. This can be due to **undershunting** or even obstruction. Shunts can also **overshunt** and of course also become **infected**. If any of you would like to know more about shunts, please Email me, and I will send you some more information once this module is completed.

NORMAL PRESSURE HYDROCEPHALUS

So, finally, we have covered the various types of HCP with raised intracranial pressure. Well, is it possible to get hydrocephalus without raised CSF due to impaired CSF drainage or overproduction? Intuitively, it seems like an obvious NO-answer, but the reality is more complex.

SLIDE 27

In fact, there is something called **normal pressure hydrocephalus**.

SLIDE 28

It is still poorly understood in terms of its underlying pathophysiology, but very clinically relevant, as it exhibits some very severe, but treatable, symptoms. Originally, NPH was considered an idiopathic condition, but as of late, it has been recognized that in some cases a **predisposing condition** has been present, e.g. post-SAH, post-trauma, post-meningitis or after surgery. In fact, it has been postulated that the enlarged ventricles that we see (hence why it is called hydrocephalus) may not be the thing that is causing the symptoms. Research is very much ongoing here.

SLIDE 29

So how do patient's with NPH present? Well, there is a classic clinical triad associated with NPH, but can be seen with other conditions such as Alzheimer's disease or Parkinson's disease.

- The first component of the triad is **gait disturbance** where patients have a wide-based gait with short, shuffling steps and unsteadiness, when trying to turn around.
- The second component of the triad is a type of **dementia** where there is memory impairment.
- The third component is **urinary incontinence**.

In NPH we do not expect to see any of the symptoms of raised ICP, such as headache, papilledema or seizures, unless there is of course some other underlying pathology.

How do we diagnose this?

SLIDE 30

The opening pressure of a random lumbar puncture will be normal, hence the name. **CT head** may indeed look rather similar to any other patient with another type of communication hydrocephalus. But in addition to this, there are a few other tests that we can do. These include ambulatory lumbar drainage or radiographic imaging. Once again though, the details if this are way beyond the scope of this video. Definitive treatment of NPH is **shunting** (preferably a VP shunt) or an **ETV**.

SLIDE 31

So to conclude, hydrocephalus is a term used to describe a complex clinical state that can be due to

- many different **etiologies**,
- be **acute** or **chronic**,
- **communicating** or **non-communicating**,
- **acquired** or **congenital**,
- occur in children and **adults**, and
- most commonly is associated with **raised intracranial pressure**, but can also go along with **normal intracranial pressure**.

There are short-term and long-term ways to treat hydrocephalus, and this will depend on

- the patient,
- their clinical state, and of course
- the underlying condition.

However, if you encounter a patient with enlarged ventricles on CT, just think logicially.

SLIDE 32

- Is the patient a **child** or **adult**?
- Is this likely to be **acquired** or **congenital**?
- Can I see any other abnormalities on **CT head**, rendering obstructive hydrocephalus a likely cause (e.g. a brain tumor)?

- What is their **previous clinical history** (e.g. post-SAH, rendering communicating HCP likely)?

Although the real world can be complex, at this point you have likely uncovered many pieces of information. You are then ready to make a referral to a neurosurgeon, and hopefully helped to save your patient from further deterioration.

FINISH WITH SLIDE 33

THE ESSENTIALS OF INTRA-CRANIAL NEURO-IMAGING

INTRODUCTION

SLIDE 1

Welcome to this video, which will take you through the essentials of intra-cranial neuro-imaging. In the video, I will introduce you to all the common neurosurgical pathologies that you will undoubtedly come across in your clinical practice. It will be a mix of pathologies, as a result of trauma, as well as other pathologies, such as cancers and hemorrhages. As a note, this video will assume some basic knowledge of how to interpret the various radiological modalities, and will focus on this from a neurosurgical point of view. That is, I won't teach you how to write a full radiology report as the radiologists do (because I can't do that anyway really), but I will rather approach this topic from the way I approach it when working: I have a systematic approach, and look for some tell-tale signs of each of the pathologies. With that said, I will introduce you to the topics we will cover.

SLIDE 2

We will cover:

- An introduction to the different **radiological modalities** used in neurosurgery to diagnose intracranial disease (with a brief mention of spinal disease), then we will move onto
- **Cranial trauma**, including skull fractures, epidural hematomas, subdural hematomas, traumatic subarachnoid hemorrhages, parenchymal brain injury and intracerebral bleeds as a result of trauma.
- Following this, we will talk about **intracranial vascular disease**. This includes aneurysms and subarachnoid hemorrhages, arteriovenous- and other vascular malformations
- Lastly, we will then talk about the various types of tumours, we can find in the central nervous system, including intra-axial and extra-axial tumors.

In this video, we won't talk extensively about spinal disease, which is a whole topic of its own. However, many of the principles I will mention with regards to intracranial disease are relevant; **anatomical location** and **nature of the lesion**, as well as **clinical deficit** will guide you towards correct diagnosis, whether due to trauma, tumor or chronic disease.

So let's begin!

THE DIFFERENT MODALITIES

SLIDE 3

So, as I am sure you know, neurosurgery uses radiological imaging a lot. And whilst CT scans are perhaps the most common scans to be performed these days, we also use everything from plain radiographs to more advanced MRIs and angiography.

SLIDE 4

The **plain radiograph** has largely been replaced by more advanced scans for imaging of the cranium (except for some pre-operative planning), but it is still a very useful modality, especially for the **spine**, as it is **cheap**, **available** pretty much **anywhere**, and exposes the patient to a relatively **low amount** of **radiation**. And when looking at a spinal radiological image, it is important to understand some basic anatomy. Nothing advanced, I promise. To prove this point, let's briefly go over it:

Let's start with the cervical vertebrae.

SLIDE 5

Here is a cervical vertebra (pick C4). What characterizes the cervical vertebrae compared to other vertebrae, is the presence of these – called **transverse foramina** [point to transverse foramina]. These allow the vertebral arteries to pass through on their way to join the circle of Willis in the brain. But even within the cervical vertebrae, there are some variations. There are **7 cervical vertebrae**.

SLIDE 6

The lower 5 of these (called C3, C4, C5, C6 and C7) are called **subaxial vertebrae**, and have the typical appearance you can see here.

SLIDE 7

The top two vertebrae, **C1** (also called **'the atlas'**) here and **C2** (also called **'the axis'** with this little process sticking out called the odontoid peg or dens) here, look a bit odd. This is because they both form a crucial join called the **atlanto-axial joint**, which is enables a joint between the spine and the head or skull that can rotate. The axis forms the pivot upon which the atlas (which carries the head) rotates. As we'll talk about later, damage, or dislocation, of this joint can have immediate disastrous consequences. **Spinal X-rays** are particularly useful for picking up chronic spinal degenerative disease and spinal trauma (so fracture, dislocations, etc).

SLIDE 8

There are a number of different views that we look at for cervical spine X-rays, and you definitely don't need to know them all. But here are a few pointers. Firstly, a common mistake is to not actually **get the full view** of the cervical spine in the image. It sounds ridiculous, but happens commonly. SO if you have ordered a cervical spine X-ray, make sure you can also see the first or couple of first thoracic vertebrae as well, as this part of the spine often becomes damaged, and for obvious reasons you really don't want to miss it.

Most cervical spinal pathology can be detected by this view here, the **lateral view**, which is taken cross-table. If patients have very big shoulder blades, they can sometimes be asked to raise one of their hands above their head, to get what is called a **Swimmer's view**, to avoid obscuring the view of the lower cervical vertebrae.

SLIDE 9

Another important view to be aware of is the **open mouth odontoid view** here, as well as the **anterior-posterior (AP)** and **flexion-extension views** here. The open mouth view is important to look at the atlanto-occipital join for any damage to the odontoid process, and the flexion-extension view are great for allowing us to assess for spinal instability in patients with neck pain (for example after trauma), where no obvious bony abnormality can be identified on the standard lateral view. There are some fancy views (like **oblique views** for diagnosing nerve root compression), but the ones I mentioned will allow you to diagnose most things.

SLIDE 10

As with the cervical vertebrae, knowing the basic anatomy of the **thoracic vertebrae** is crucial.

SLIDE 11

The unique feature to look for to identify a thoracic vertebra is the presence of these here: **the costal facets which articulate with the heads of the ribs.** Thoracic vertebral X-rays are really not as useful as cervical ones, because of the ribs obscuring much of the useful anatomy. However, in the trauma setting.

SLIDE 12

AP and lateral X-rays of the thoracic vertebrae are still used to find things like fractures

SLIDE 13

The **lumbo-sacral vertebrae** are the largest of them all.

SLIDE 14

They can be distinguished from the cervical and thoracic vertebrae by their lack of costal facets or transverse foramina, their large transverse processes here, and small spinal processes, as you can see here.

SLIDE 15

The five sacral vertebrae are fused into this wedge shaped structure – **the sacrum**, which articulates with the fifth lumbar vertebra and the ilia. For the lumbo-sacral vertebra, we use **AP, lateral, flexion-extension** and **oblique views**.

SLIDE 16

The AP and lateral views are great to identify fractures and subluxations, or as in this lateral view, ankylosing spondylitis. Instability of the spinal ligaments can be identified by the flexion-extension views, or if one vertebra is displaced over the other (i.e. not normally aligned), a condition we call spondylolisthesis. Oblique views are good for identify spondylolysis as you can see here, an acquired or congenital condition where this this, the pars interarticularis, is separated, thus increasing the risk of spondylolisthesis.

Let's move onto the CT scan and focus on intracranial imaging.

SLIDE 17

THE CT SCAN

The **CT scan** has been widely used ever since it was introduced in the 1970s, and in addition to giving us a useful **cross-sectional view**, the **attenuation properties** of the tissues to X-rays used in a CT scan, allow us to define different tissues of the brain and spine. The attenuation properties of the tissues are defined in terms of Hounsfield units, which range from -1000 (air) to +1000 (bone). In practical terms this means that the denser tissues (such as bones, or foreign bodies like metal) appear white, and air or water appear black on CT scans. If we then add contrast, we can make these less dense structures appear white, to more easily delineate them. CTs are great to diagnose **acute neurosurgical pathology** in the brain and spine (fractures, edema, infarction, hemorrhage, mass lesions and hydrocephalus), do often **not require any particular prep**, are **performed in a few minutes**, and are relatively **easy to interpret**. I will show you a lot of CT scans later.

SLIDE 18

ANGIOGRAPHY

So briefly, I'll mention angiography, a modality in which we can look at the blood vessels of the brain and spine. Obviously, angiography is very useful for looking at aneurysms (as pictured here) or arterio-venous malformations, but it can also be used to define cerebral anatomy, shift, edema, mass effect upon blood vessels caused by a tumor, and of course blood vessel occlusion. Apart from playing an important role in **diagnosis**, angiography is also used in **intervention**, for example when coiling aneurysms or when treating cerebral artery vasospasm.

SLIDE 19

MRI

Finally, let's talk about MRI, which has become increasingly useful in neurosurgery. I am certainly no physics professor, but basically, the differing proton content, and their spin of the different tissues, is what makes us able to differentiate them on **MRI scan images**. There are three types of MRI scans used (or acquisitions): **T1**, **T2**, and **proton density**, which allow us to more readily visualize different tissues. In T1 images, gadolinium, a contrast-agent, appears hyperdense and normally the brain tissues should not be permeable to contrast agents, because of the blood-brain barrier. However, if there is an impaired blood brain barrier (e.g. because of a tumor, infection, or vascular abnormality), or if there is no blood brain barrier (e.g. with the pituitary gland), then the contrast agent can get into the tissues and show preferential enhancement on the scan images.

SLIDE 20

THE PATHOLOGIES

SLIDE 21

Right, so now that you know about the essential imaging modalities, let's get on with our whistle-stop tour of the various pathologies that we diagnose with them.

SLIDE 22

Let's start with cranial trauma.

SKULL FRACTURES

SLIDE 23

The **initial CT** done on patients with head trauma can pick up about two thirds of all skull fractures, but importantly – the severity of these does not necessarily correlate that well with the severity of possible injury of the brain inside the skull.

SLIDE 24

There are three types of skull fractures.

- linear fractures,
- depressed fractures and
- diastatic fractures.

SLIDE 25

As you can see here, **linear fractures** are just that, linear and not displaced. They can be associated **epidural hematomas** because of damage to the dura below, so remember to carefully also look for this if you spot a linear skull fracture.

Depressed skull fractures are also what it says on the tin, displaced. This means that these, the diploic tables of the skull are displaced in relation to each other. Often these occur when **smaller objects hit** the skull at high speed (think golf ball), and are more commonly associated with **parenchymal brain injury**.

Diastatic fractures occur mainly in children and occur **along the suture lines** of the skull. If this occurs together with a tear to the dura, the brain, and associated meninges, may form an outpunching, called a **leptomeningeal cyst** or growing skull fracture. This needs to be sorted out with surgery and repair.

SLIDE 26

As with any fracture anywhere in the body, skull fractures can be open or closed. **Open fractures** are also associated with a **laceration to the scalp**, leading to potential communication between the outside environment and the intracranial contents, and a potential **infectious hazard**.

SLIDE 26

If the fractures cause a tear of the dura that is associated with the paranasal sinuses or mastoid air cells, patients may present with CSF leaking from their nose or ears. If we perform a CT scan on these patients, we might see **pouches of air (blackness)** around the paranasal sinuses – we call this **pneumocephalus**. Pneumocephalus elsewhere in the brain may be caused by other things like post-operative, or infection. Fractures of the base of the skull can be identified, if we perform a CT with very thin slices.

EPIDURAL HEMATOMAS

SLIDE 27

Epidural hematomas occur with **trauma**, when a fracture shears the **middle meningeal artery** or a **dural venous sinus**, causing collection of blood between **the skull and dura mater**. They are more commonly found unilaterally and in the **temporal area** (because the skull is thinner here and the middle meningeal artery runs here). The dura is more adherent to the skull along the suture lines of the skull, so this normally limits epidural bleeds along the suture lines.

SUBDURAL HEMATOMAS

SLIDE 28

Subdural hematomas also occur frequently with **trauma** in 10-20% of head injuries. Blood will collect between the **dura mater** and the **arachnoid mater**, for example after there has been an acute change in velocity (think car accident), causing the **tearing of**

the bridging veins. **Chronic subdurals** may also occur as a result of **minor trauma**, especially in elderly patients who have more brain atrophy.

SLIDE 29

Acute SDHs appear **hyper-dense** (so more white than the brain), and **crescent-shaped** on a non-contrast CT scan. Sometimes they might not appear so dense, when there is some unclotted blood of CSF mixed with areas of clotted blood. As the clot gets older, it becomes less dense and eventually the same density as the brain – isodense. **Chronic** subdural bleeds appear **hypodense** – less dense than the brain – so darker, but may also be denser, if there is re-bleeding or membrane formation from neo-vascularization.

SLIDE 30

TRAUMATIC SUBARACHNOID HEMORRHAGE

Traumatic subarachnoid hemorrhage is perhaps not something that is top of mind for many non-neurosurgeons, but it is in fact rather common, and present in the majority of cases of **moderate to severe head trauma**. As a result of head trauma and shearing of blood vessels, blood collects in the subarachnoid space, which is formed between the **arachnoid membrane** and the **pia mater**.

As you can see on this non-contrast CT, it presents as a **hyperdensity** – so white – following the sulci over the cerebral convexities. In addition, we see blood down here, in the **CSF cisterns** at the base of the brain.

PARENCHYMAL BRAIN INJURY

SLIDE 31

Obviously head trauma can also cause damage to the brain tissue itself in various ways in the form of a bleed due to parenchymal vessel rupture, **cerebral contusions**, **diffuse axonal injury**, and **brainstem hemorrhages** (also called Duret hemorrhage).

Diffuse axonal injury, illustrated here, may not even be visible on CT scans or, as you see here, presents itself merely as some diffuse edema. **MRIs** are much better for detecting DAI, and on a T2 weighted image we will see multiple poorly defined, hyperdensities in the white matter of the brain. This type injury occurs when **the axons are sheared** as a result of acceleration/deceleration or violent rotation movements (think car accident).

In a patient who comes into the ED after **a car accident**, there are three areas to carefully look for any kind of diffuse edema:

- the gray-white junction,
- the corpus callosum, and
- the dorso-lateral aspect of the brainstem.

Contusions seen here occur when the brain impacts the skull, and frequently occur in these two areas: the **frontal pole** of the brain and the **temporal part** of the brain. Depressed skull fractures may also cause contusions. As seen here, they present as multiple hyper densities in the areas affected.

SLIDE 32

Right, so now that we have covered most of the trauma that can occur in the brain. Let's look at another big topic – intracerebral [change to this from intracranial] hemorrhage. What does it look like on imaging?

INTRACRANIAL HEMORRHAGE

INTRACEREBRAL HEMORRHAGE

SLIDE 33

The first type of bleed I will talk about is the **intracerebral hemorrhage** which occurs as a result of one of many different reasons:

- hypertension,
- amyloid angiopathy,
- hemorrhagic infarction,
- ruptured cerebral aneurysm,
- arteriovenous malformation (AVM),
- hemorrhagic tumors or cysts,
- encephalitis, or
- vasculitis.

These patients are very, very sick, so if this is suspected, a **CT scan** should be performed ASAP and will show either the presence or absence of blood. If this occurs in a patient with a brain tumor, an **MRI** or **CT angiography** should also be performed to ascertain whether there is any vascular abnormality driving the haemorrhage.

Hypertension is by far the most common cause of intracerebral haemorrhage.

Patients who have had an ischaemic stroke or infarction (both venous and arterial) may also get a **hemorrhagic conversion**, that is, they may develop a bleed in the area that was infarcted: in fact, about 5-15% of patients with ischaemic stroke go through this. This happens as a result of **reperfusion** of the infarcted area, normally within 24-48 hours of the ischemic event. As you can see here, it presents on the CT scan as hypodensity distributed in a vascular manner, with possible areas of hyperdensity within.

More often than you think, **brain tumors** present with a hemorrhagic event. Having a brain tumor predisposes to ICH for a number of reasons, including

- neovascularity,
- necrosis,
- vascular invasion, and
- being in a pro-coagulant state.

Some of the tumors I will show you later – glioblastomas, oligodendrogliomas, pituitary adenomas, and hemangioblastomas, are particularly prone to bleed, as well as metatstatic tumors with primary malignancies in the skin, kidneys and lung. Here you can see a hematoma with a lot of edema surrounding it. This raises the suspicion of there being an underlying malignancy, and so a contrast **CT** or **MRI** should be performed to rule this out, **in addition to a non-contrast CT**.

As you know, the brain is associated with a whole range of vasculature, and thus is predisposed to a lot of potential disease.

ANEURYSMS AND SUBARACHNOID HEMORRHAGE

SLIDE 34

Previously, I mentioned traumatic subarachnoid haemorrhage, but **subarachnoid haemorrhage** occurs frequently without any trauma. The most common cause of non-traumatic cause of a non-traumatic subarachnoid haemorrhage is **a cerebral artery aneurysm** or **AV-malformation.** There are many types of aneurysms, but you do not need to know all – the one here is a Berry aneurysm of the Circle of Willis.

This is a CT scan of a patient who has suffered a large subarachnoid hemorrhage after an **aneurysm** has burst. We can see here that the blood from the hemorrhage appears as high density, so whiter than the brain, and collects in the basal cisterns. Here is another image where the blood has collected in the **Sylvian fissure** – which occurs after aneurysms in the middle cerebral artery, terminal internal carotid artery or posterior communicating artery. Here is another bleed. The high density blood is seen in the **interhemispheric fissure** as result of either an anterior cerebral artery or anterior communicating artery aneurysm. We may also see the **fourth ventricle filled** with blood – which tends to occur as a result of a burst aneurysm of the posterior inferior cerebellar artery. Whilst it may not be terribly important for you to remember where the blood from all these different aneurysms tends to collect after a hemorrhage, it is useful to know the simple fact that **the distribution of blood gives us a clue of where the aneurysm occurred on just a non-contrast CT**, even prior to performing any CT or MRI angiography. If the subarachnoid hemorrhage is subacute or chronic, we may not see it on CT.

SLIDE 35

So after someone has had a non-contrast CT confirming a subarachnoid hemorrhage, further imaging must be performed, and **cerebral angiography is the gold standard for diagnosing cerebral aneurysms**. The angiography allows us to:

- detect the culprit aneurysm, but also other aneurysms,
- define the anatomy of the aneurysm neck,
- look for perforating arteries,
- identify collateral circulation, and also
- diagnose the severe complication of vasospasm that tends to occur in the aftermath of subarachnoid hemorrhages.

Here you can see an aneurysm of the anterior communicating artery before and after endovascular coiling.

The location of the aneurysm as per angiography can then be matched with the location of the bleed on the non-contrast CT, to confirm that we have found the culprit aneurysm. Furthermore, an aneurysm that has burst tends to be **large, irregular** and have **outpouchings**.

SLIDE 36

AVM AND VASCULAR MALFORMATIONS

In addition to aneurysms, some other things can go wrong in the vasculature of the brain, where there are either abnormal connections between arteries or veins, or there is malformation of vessels. These include arterio-venous malformations, cavernous angiomas, capillary telangiectasias, and venous angiomas.

SLIDE 37

What you can see here is an **arterio-venous malformation** (or AVM, as we call them). They are the result of arteries connecting directly to veins through fistulae, and 4% of them hemorrhage every year. Normally tortuous arteries will feed into them, and large veins drain them – all visible on **CT**. They most commonly present as an intracerebral hemorrhage, but can also present as a seizure, or focal neurological deficit as a result of mass effect, for example. As you can see, on the CT it is isodense (so a similar density to the brain), show flow voids (indicative of active blood flow) and potentially also some calcifications. Contrast will help to enhance the vessels associated with it – indeed, any patient with a suspected AVM on non-contrast CT must have **angiography** performed as well. Angiography will help to identify a number of features including the feeding arteries, as seen here, the actual fistula between the artery and vein (we call this the nidus), and the draining veins. In addition, an **MRI** can be used to define the effect that the AVM has on the surrounding cerebral anatomy.

SLIDE 38

Cavernous malformations or angiomas are cystic vascular sinusoids linked with a vascular endothelial layer, with no neural tissue in association with it. The flow of blood through these is much lower than the flow in AVMs, and so they rupture much less often than AVMs – at around 0.5 % per year, but present in a similar way to AVMs, so with hemorrhages and seizures. On CT and MRI they will look like bits of popcorn as you can see here, because of multiple hemorrhages of different ages and with different levels of calcification. They might also have this classical appearance on T2 MRI with a hemosiderin ring. They are not detectable on angiography.

SLIDE 39

Venous angiomas are essentially bunches of large veins in the white matter surrounding the ventricles, and they normally drain into a large draining vein. They are difficult to find on non-contrast CT, but on contrast CT or MRI they will show up like they do here – with the 'caput medusa sign' - like a tuft of vessels adjacent to a ventricle. On angiography we will see dilated venous structures.

Finally, capillary telangectasias are nests of dilated capillaries, with normal neural tissue interspersed within. We commonly find them in the pons, cerebral cortex or within the spinal cord. They are most visible on CT or MRI angiograms.

BRAIN TUMORS

SLIDE 40

Let's move onto talk about brain tumors and how we diagnose various types on radiological imaging. Brain tumors are complex and in order to prevent this video from being 13 hours long, I do not intend to in anyway go over all the different types and each of their particular characteristics. However, I am going to swiftly talk about some of the commonest primary brain tumors within the central nervous system as well as describe the characteristics of metastatic lesions in the CNS.

INTRA-AXIAL BRAIN TUMORS

SLIDE 40

When talking about tumors of the central nervous system, it is helpful to think of them in terms of intra-axial and extra-axial lesions. Intra-axial lesions are those WITHIN neural tissue (the axis), and EXTRA-axial tumors are those in the structures surrounding the CNS, so the meninges for example.

SLIDE 41

Intra-axial tumors can be one of two types: either those that are primary brain tumors, i.e. they originate from the neural tissues themselves, or metastases, i.e. the primary tumor is elsewhere, for example in the kidneys or lungs. There are many different types of primary brain tumors, named according to which tissues they arise from: gliomas (including astrocytoma, anaplastic astrocytoma, glioblastoma multiforme, oligodendrogliona and ependymoma), neuronal origin tumors, pineal region tumors and lymphomas. And obviously metastatic disease can deposit anywhere within the CNS. Let's look at the commonest types of primary brain tumors.

SLIDE 42

Gliomas are by far the most common type of primary brain tumors, and what you see here, an astrocystoma, a tumor of the astrocytes, is the most common subtype of glioma. Gliomas are normally rather diffuse and infiltrate, but can also be well-defined, as you see in this MRI of a 28 year old male, with an almost cyst like appearance. As you can see here, a well-circumscribed lesion is more likely to be another subtype of glioma, like a pilocytic astrocytoma or subependymal giant cell astrocytoma. Of course, definitive histological diagnosis relies on biopsy.

Gliomas may only look like a bit of edema in the white mater, or perhaps a poorly defined isodense entity within the white matter. In adults they are normally found supra-tentorially (so the area here, above this structure called the tentorium cerebelli), and in children infra-tentorially (so below the tentorium cerebelli). Tumors of high grade, so for example anaplastic astrocytomas or glioblastomas, enhance very well when contrast is added, as you can see here, whereas low-grade astrocytomas enhance poorly. In addition, there might be areas of necrosis or hemorrhage in the core region of the tumor. The high grade tumors often spread through edema or enhancement along tracts of white matter, such as the corpus callosum, as a result of their infiltrative nature.

MRIs are very useful to differentiate low-grade astrocytomas from high-grade anaplastic astrocytomas and glioblastoma multiforme.

Both low-grade astrocytomas and high-grade anaplastic astrocytomas and glioblastoma multiforme are iso- or hypo-intense on T1 MRI images. However, on T2 weighted MRI images, low-grade tumors are more homogeneously hyperintense, and high-grade tumors look a bit more patchy – that is they are heterogeneously hyperintense. Being able to see this difference is not easy at first, and requires some practice. However, it is a useful rule of thumb to be aware of.

SLIDE 43

Here is an image of a pilocytic astrocytoma, a tumor that is glial origin and mainly occurs in children or adolescents. These are much more well-defined than the tumors we previously spoke about, and tend to occur near the third or fourth ventricles, arising from the cerebellum, optic chiasm, hypothalamus, or brain stem as seen here. As you can see here, they have a cystic appearance on CT and MRI, with an enhancing nodule within.

SLIDE 44

Here is is a CT of an oligodendroglioma, and an MRI of another oligodendroglioma. These are slow growing and arise from, as the name implies, oligodendrocytes. Normally they are located within the cerebral hemispheres, and specifically in the frontal lobes. As you can see here, they have a patchy, or heterogeneous appearance, they enhance rather well and often have areas of calcification.

SLIDE 45

The final primary brain tumor I will mention is the ependymoma. These are, as the name also implies, derived from ependymal cells, the cells that surround the cerebral ventricles, most commonly in the fourth ventricle (so infratentorially). They are isodense tumors with areas of hyperdensity within on non-contrast CT, due to calcification, as you can see here. They can often grow into the ventricle.

SLIDE 46

METASTASES

Metastases in the brain represent a big proportion of brain tumors – about 25-30%, and arise from a range of tumors in other body systems, such as the lung, skin, kidneys, breast, gastrointenstinal system or the genito-urinary system. On the left we see two images of a woman who has metastases in her brain due to breast cancer, and on the right brain metastasis from melanoma. As demonstrated here, metastases are seldom solitary, and there tends to be multiple metastases on presentation. They can occur pretty much anywhere in the brain, and appear hyper-dense in general. A useful rule of thumb is that if a patient has multiple lesions in the brain, they are likely to be metastatic, as primary brain tumors normally do not multiply within the brain. Cerebral abscesses can sometimes look very similar to metastases, so a good clinical judgment and biopsy are important complements to the investigation.

SLIDE 47

EXTRA-AXIAL BRAIN TUMORS

In the final part of this video, I will go over extra-axial brain tumors. These tumors are generally benign (but that does not mean they do not cause problems!), and include meningiomas, vestibular schwannomas, pituitary tumors, dermoids and epidermoids. Some can be malignant – like the malignant meningiomas or sarcomas.

SLIDE 48

Meningiomas are common and originate from the arachnoidal cap cells here, meaning that they can arise from any surface that has arachnoid tissue: for example, the sagittal sinus, cerebral convexity, sphenoid ridge, olfactory groove and posterior fossa. Plain X-rays show thickening of bone (what we call hyperostosis) next to the meningioma, and dilated vasculature entering the tumor. As you can see on this CT, the mass is well-defined and hyperdense, and is right adjacent to the dura. These lesions may also calcify and have edema around them. They enhance strongly with contrast on both CT and MRI, as seen here on the right.

SLIDE 49

This tumor is a vestibular schwannoma, also called an acoustic neuroma and occurs in this region of the brain between the cerebellum and pons – the cerebellopontine angle, often extending into the auditory canal. It is a benign tumor, and arises from the nerve sheath of the vestibular portion of the eigth cranial nerve, the vestibule-cochlear nerve. They are well-circumscribed and, they are well-enhancing and iso/hypo-dense on CT scans, and enhance well on MRIs, as you can see here.

SLIDE 50

As you can imagine, pituitary adenomas arise from the pituitary, and they comprise a significant proportion of all intra-cranial tumors we see in clinical practice. They are normally called either micro-adenomas (meaning they are less than 10 mm in diameter) or macro-adenomas (which are more than 10 mm in diameter).

These tumors are often slow growing, and given that they are in the pituitary, about half are endocrinologically active, meaning that they produce some kind of endocrine substance, like prolactin for example, in the case of prolactinomas as seen here, a tumor arising from the prolactin producing cells. Microadenomas are generally hypodense on CT and MRI after we apply contrast (as the normal pituitary enhances more) and macroadenomas are more dense. As with some of the other brain tumors, cysts, hemorrhage (as you can see in this image) and necrosis can be seen within the macroadenomas.

SLIDE 51

HYDROCEPHALUS

Hydrocephalus is a condition that can be caused by many different types of brain pathology. Simply put, it means that the ventricles are enlarged leading to elevated intracranial pressure. Hydrocephalus can either be due to lack of adequate absorption by the structures responsible (the arachnoid granulations) which we call communicating hydrocephalus, or because of blockage somewhere along the path of CSF flow, what we call non-communicating hydrocephalus.

SLIDE 52

Here is a patient with a brain tumor. As you can see, the ventricles are only enlarged proximal to the tumor. Any mass can cause this including cysts.

In contrast, here is a patient who has suffered a subarachnoid hemorrhage, which has disrupted the absorptive ability of the arachnoid granulations, leading to uniform or symmetric enlargement of the ventricles.

SLIDE 52

CEREBRAL ABSCESSES

The final thing I will mention are cerebral abscesses – when bacteria spread into the brain either through direct spread (after surgery for example) or through the blood (for example in the case of tuberculosis), and causes parenchymal bacterial infections.

SLIDE 53

Cerebral abscesses may be either multiple if the spread is from an extra-cranial site like the lung, or solitary if they originate more locally, say from the paranasal sinuses. The appearance of these lesions changes with time: from being ill-defined in the early stages, to showing the characteristic ring-enhancement around an area of necrosis with areas of edema around it, as shown here. Also note, that some of the brain tumors I mentioned previously may have a similar appearance, so clinical history, examination and work-up are all important to complement the radiological information.

SLIDE 54

FINAL WORDS

Right, so as you have experienced, intra-cranial neuro-imaging is complex, and good diagnosis relies on knowledge of anatomy, cell biology along with adequate clinical judgment. However, as with anything in medicine, a thorough clinical history and examination will aide the radiological diagnosis immensely. Often, you can almost guess what the patient will have on a scan, merely by knowing the symptoms and signs that they exhibit. And just remember, you are never alone – there are seniors and radiologists who will help you interpret whatever scans are thrown at you.

SLIDE 55

I hope you enjoyed this video. As always, if you have any questions, concerns or would like to know more, feel free to contact me.

Appendix C. Miscellaneous

NBME Criteria used for Question Writing and Reviewing

- *Each item should focus on an important concept or testing point*
- *Each item should assess application of knowledge, not recall of an isolated fact*
- *The item lead-in should be focused, closed, and clear; the test-taker should be able to answer the item based on the stem and lead-in alone*
- *All options should be homogeneous and plausible, to avoid cueing to the correct option*
- *Always review items to identify and remove technical flaws that add irrelevant difficulty or benefit savvy test-takers*

Flaws Related to Irrelevant Difficulty	***Flaws Related to Testwiseness***
• Options are overly long or complicated *• Numeric data are not stated consistently* *• Terms in the options or the stem are vague* *• Language or structure of the options is not homogeneous*	*• Grammatical cues exist because one or more distractors don't follow grammatically from the stem* *• Options are cued by being paired or exhaustive, where some options can be eliminated because other* *Options cover all possible outcomes* *• Absolute terms such as "always" or "never" are in some options*

Introductory Emails sent to Clerkships

Dear All,

Ahead of tomorrow's session with me (4-5 pm in the Martin Conference room), I wanted to just introduce myself and the learning experience you will take part in from tomorrow (I appreciate that two of you have already gone through this process once in a previous clerkship for a couple of videos - so let's discuss tomorrow!).

My name is Dr. Carl Gustaf Axelsson, I am a neurosurgery trainee, and I am currently pursuing some research here at MGH and Harvard Medical School. I am passionate about medical/surgical education, and I am exploring whether concept videos in the context of teaching basic neurosurgery concepts to medical students are useful, in terms of both enabling medical students to learn more, as well as increase their self-efficacy, or confidence, in their own ability. As we know, the high-pressured neurosurgical and acute neurology working environment sometimes leaves little time for teaching medical students. Yet, all medical students should be trained to diagnose and treat neurologically unwell patients, but literature shows that they often lack this ability and also have low self-efficacy for doing this. My belief is that technology could be used to address this gap by improving the learning environment for medical students.

This study will cover four key topics in neurosurgery: Hydrocephalus, Intracranial hemorrhage, Neuro-imaging and the Glasgow Coma Scale. As part of this study, I'll give half of you access to two concept videos I have developed, and the other half access to two other concept videos, and all of you will get access to the learning objectives to all four topics. You will all get a pre-test, and then after two weeks a post-test and a self-efficacy test, as well as access to the two other videos. I will send out the links for the videos after tomorrow's session.

This does not in anyway affect your overall grade, and is merely a learning experience for you, whilst also contributing to valuable information on how the learning experience could be improved for you as students.

I greatly appreciate you being part of this, and I am certain you will find this a very useful learning experience. Feel free to Email me with any questions! Otherwise, I will see you all tomorrow.

Thank you and see you tomorrow!

Carl Gustaf

Concept Video Links: Email sent out to cohort

Dear All,

It was a pleasure to meet you all in the week, and thank you once again for your great effort on the multiple-choice questions, and the self-efficacy assessment. Now we can go ahead and move onto the fun part!

I have randomized your cohort into two groups. One of the groups will receive links for two videos covering two of the concepts, and the other will receive links for two other videos covering the two other concepts. Attached (PDF) are some learning objectives for all the four different concepts. In two weeks from now, we will do another quiz (post-test) and self-efficacy assessment covering all four concepts.

A few points:

1) Please do **NOT** share the link for your video with any colleagues, either within the PCE surgery cohort or beyond. This may of course affect the scientific learning study negatively, and any conclusions drawn from it. This study is due to take place in a number of clerkships, and so this is a very important point, and I would be extremely grateful, if this is adhered to.

2) As you are given the learning objectives for all the different concepts, you are of course free to find information pertaining to these. However, the videos that you receive will cover everything you need to know for that particular concept, and **no additional resource** is necessary.

3) You are of course free to view the videos as **many times** as you like!

4) For the concepts where you do not have access to any videos, you are welcome to use whatever sources you find appropriate, including basic textbooks, Wikipedia, eMedicine.

Here are the links for the videos:

Hydrocephalus:

https://hms.mediasite.video.harvard.edu/Mediasite/Catalog/Full/1c4760fe5b1b49e0b065d5e00b5f735721

Intracranial Hemorrhage:

https://hms.mediasite.video.harvard.edu/Mediasite/Catalog/Full/4d85304f791d4c4d89e74d1c8a65161421

Once again, it is a pleasure to work with you all on this. I really want to make sure this is a great learning experience for you, so please do not hesitate to contact me at any point, if you have questions or feedback. I will send you all a check-in Email at the end of the week.

See you on the 27th of February! Have a wonderful week!

Gustaf

Reminder Email sent to cohort

Dear All,

I hope you have all had a great week so far! Just a friendly reminder to have a look at the two neurosurgery concept videos each of you were sent. I hope you find them useful, and your participation is greatly appreciated!

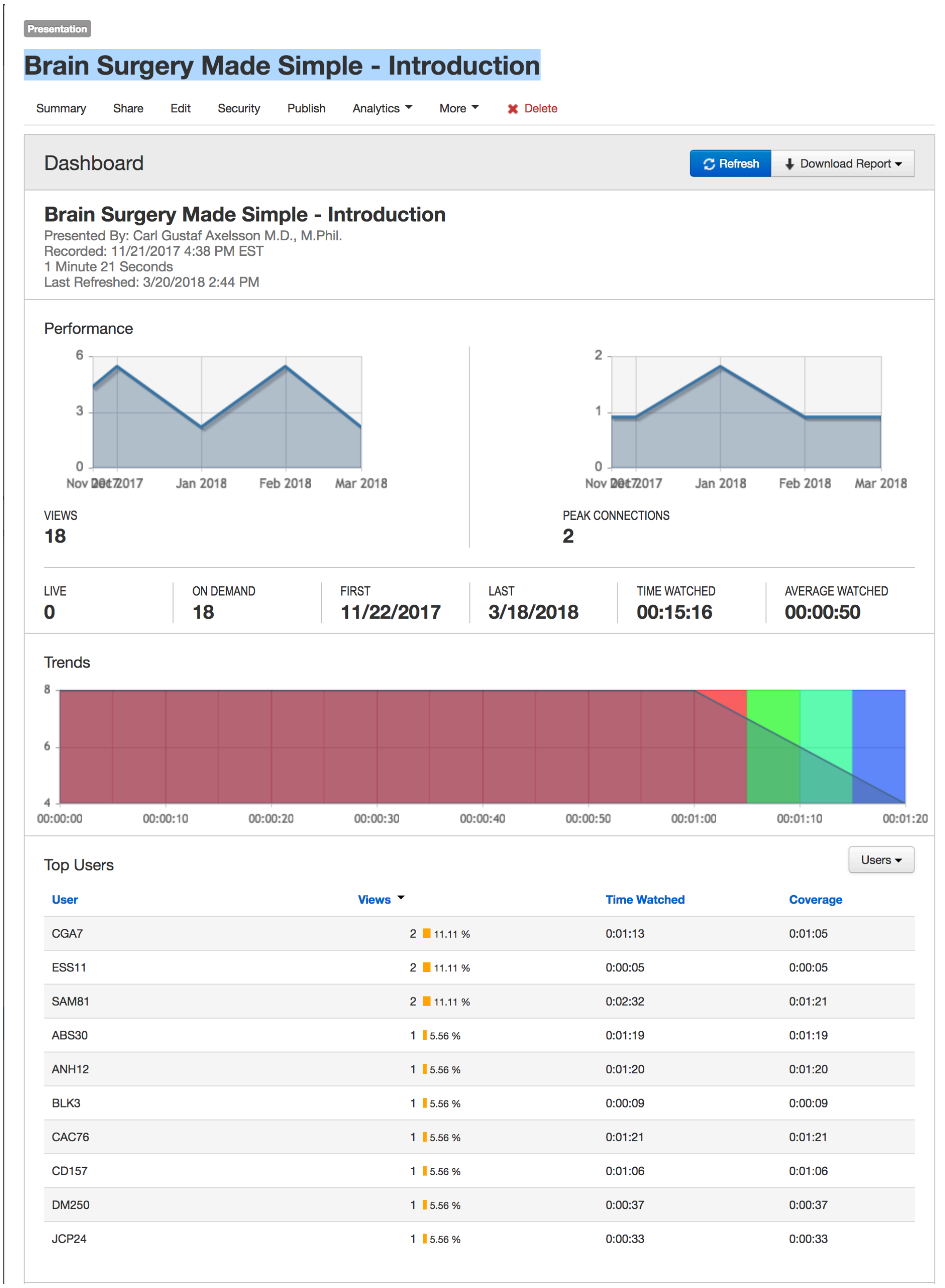
I will see you next week on Friday. Please feel free to Email me any questions you may have before then.

Have a good weekend!

Carl Gustaf

Video analytics

Example of Video Analytics Data to check compliance and access



Default Report

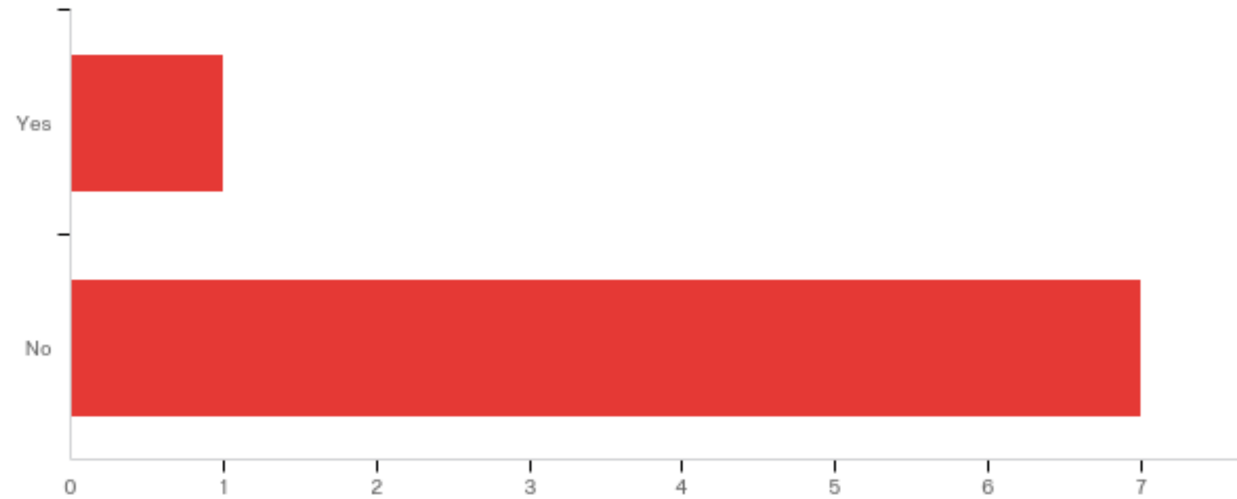
Brain surgery and Asynchronous, Video-Based Learning

April 12th 2018, 9:03 pm MDT

Q1 - Please enter the year you graduated medical school.

Please enter the year you graduated medical school.
2010
2011
2011
2009
2011
2009
2011
2011

Q5 - During medical school, did you receive any formal training in neurosurgery?

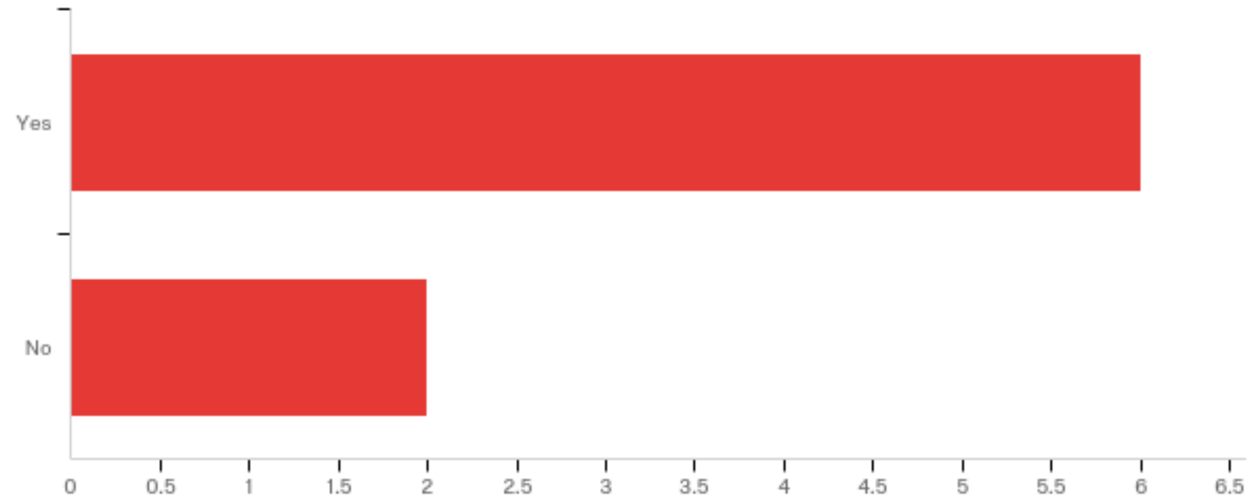


#	Answer	%	Count
1	Yes	12.50%	1
2	No	87.50%	7
	Total	100%	8

Q13 - If so, approximately how many days of neurosurgery did you experience?

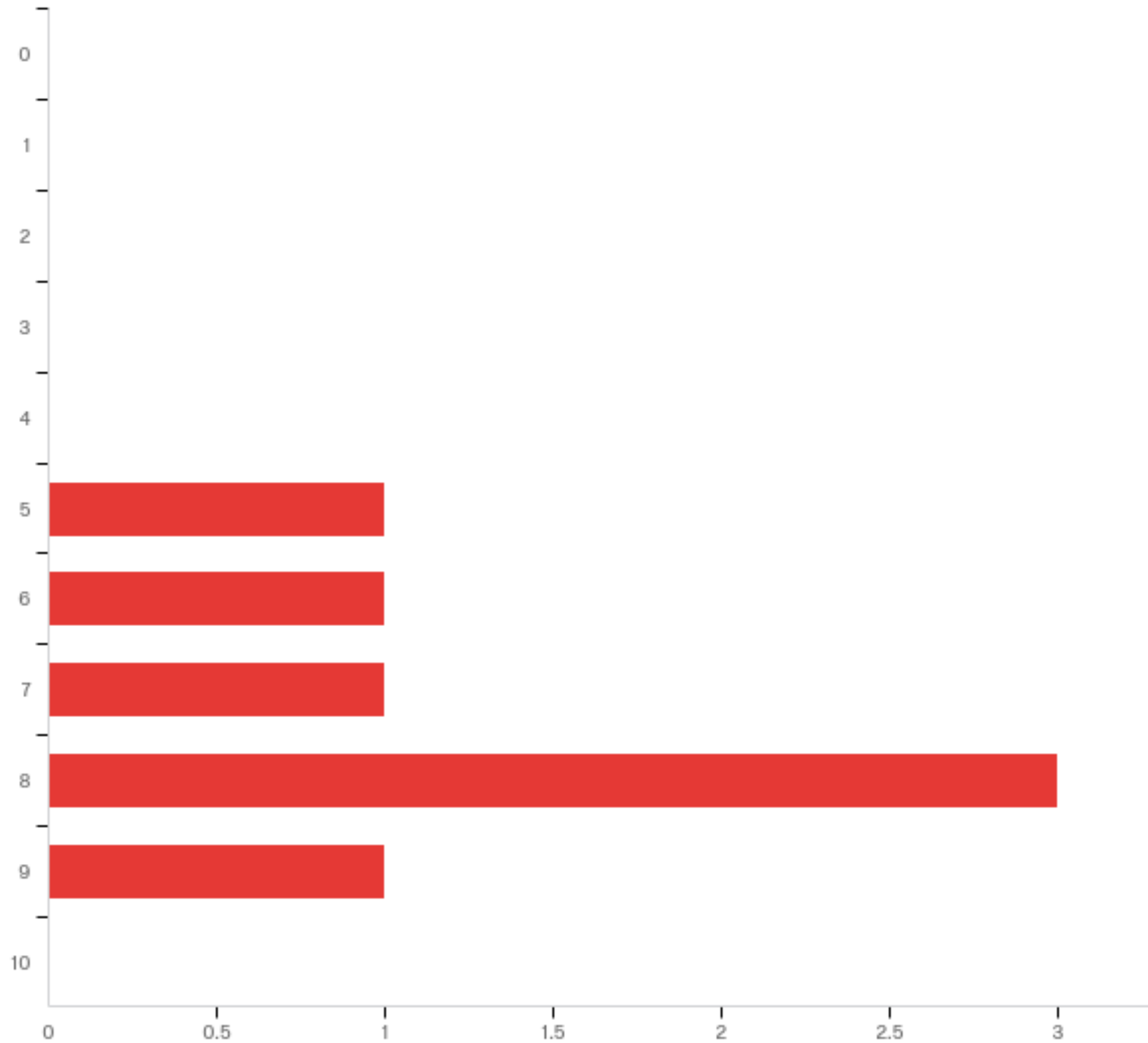
If so, approximately how many days of neurosurgery did you experience?
5
NA

Q4 - Have you ever used concept videos (i.e. short educational videos) as a learner?



#	Answer	%	Count
1	Yes	75.00%	6
2	No	25.00%	2
	Total	100%	8

Q6 - Please rate how useful these videos were to your learning (0= Not useful, 10 = Extremely Useful)



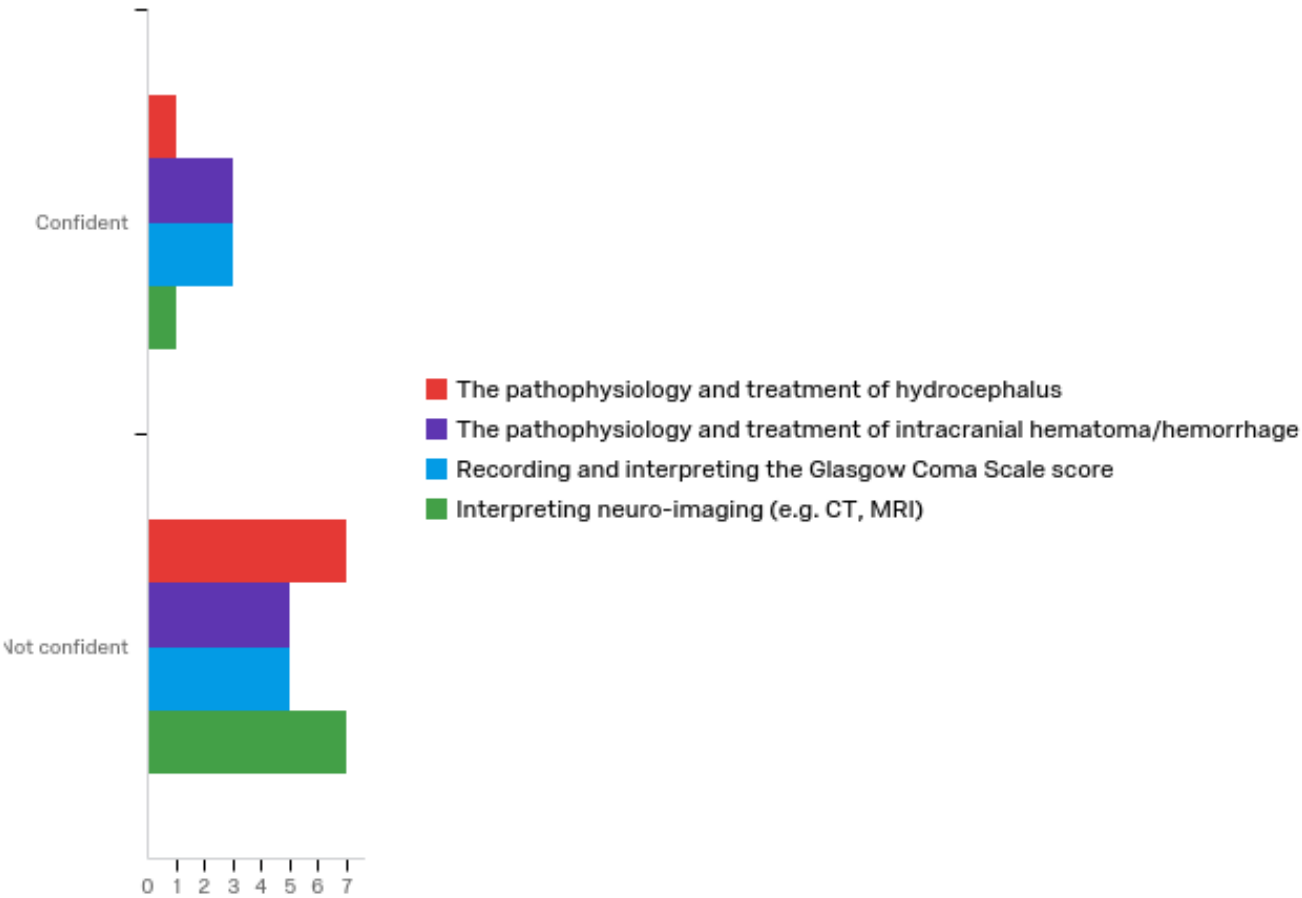
#	Answer	%	Count
0	0	0.00%	0
1	1	0.00%	0
2	2	0.00%	0
3	3	0.00%	0
4	4	0.00%	0

5	5	14.29%	1
6	6	14.29%	1
7	7	14.29%	1
8	8	42.86%	3
9	9	14.29%	1
10	10	0.00%	0
	Total	100%	7

Q7 - Please comment on why these videos were useful/not useful.

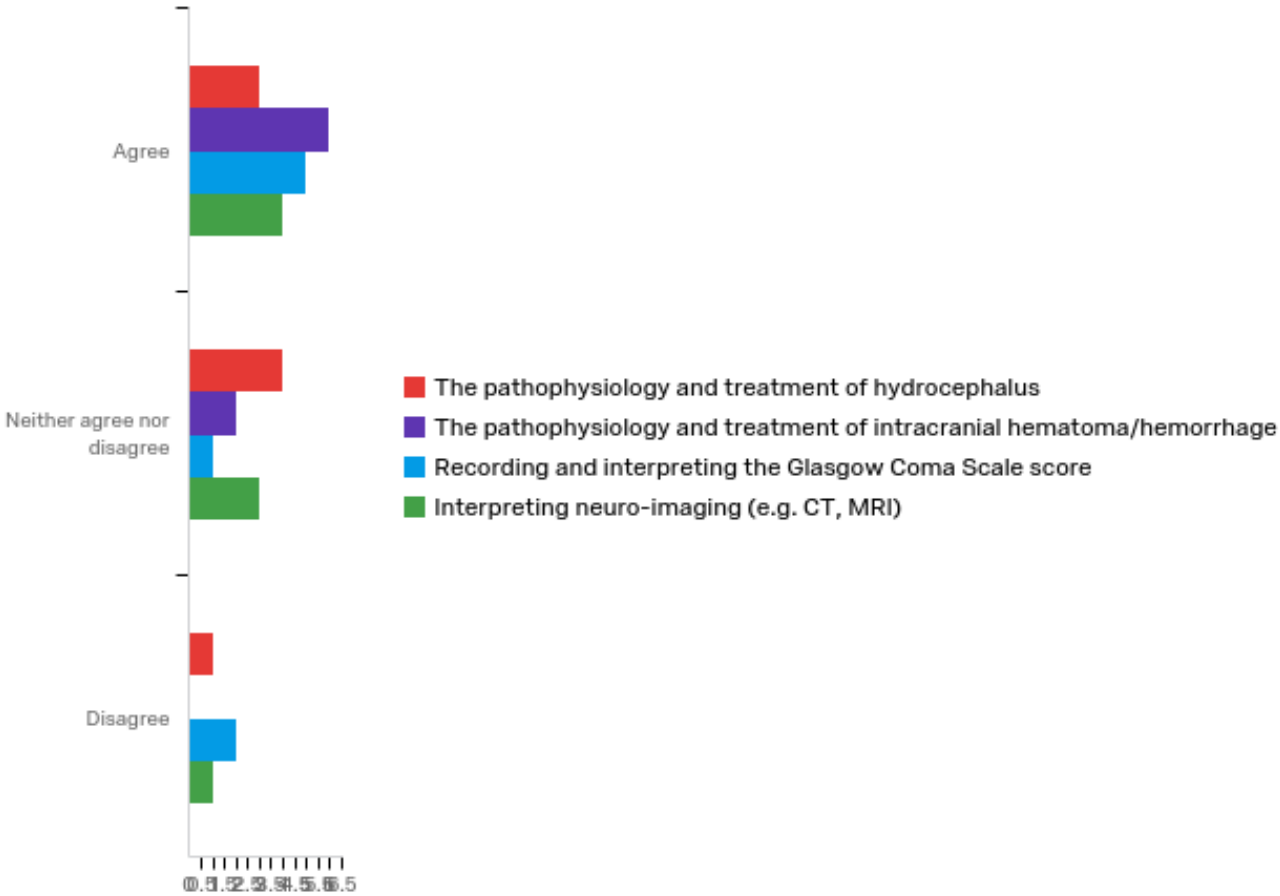
Please comment on why these videos were useful/not useful.
short, to the point, very focused and clinically relevant
N/A - haven't used them
Probably useful for procedures
Good way to distill information

Q9 - How confident would you say that you are with the following concepts?



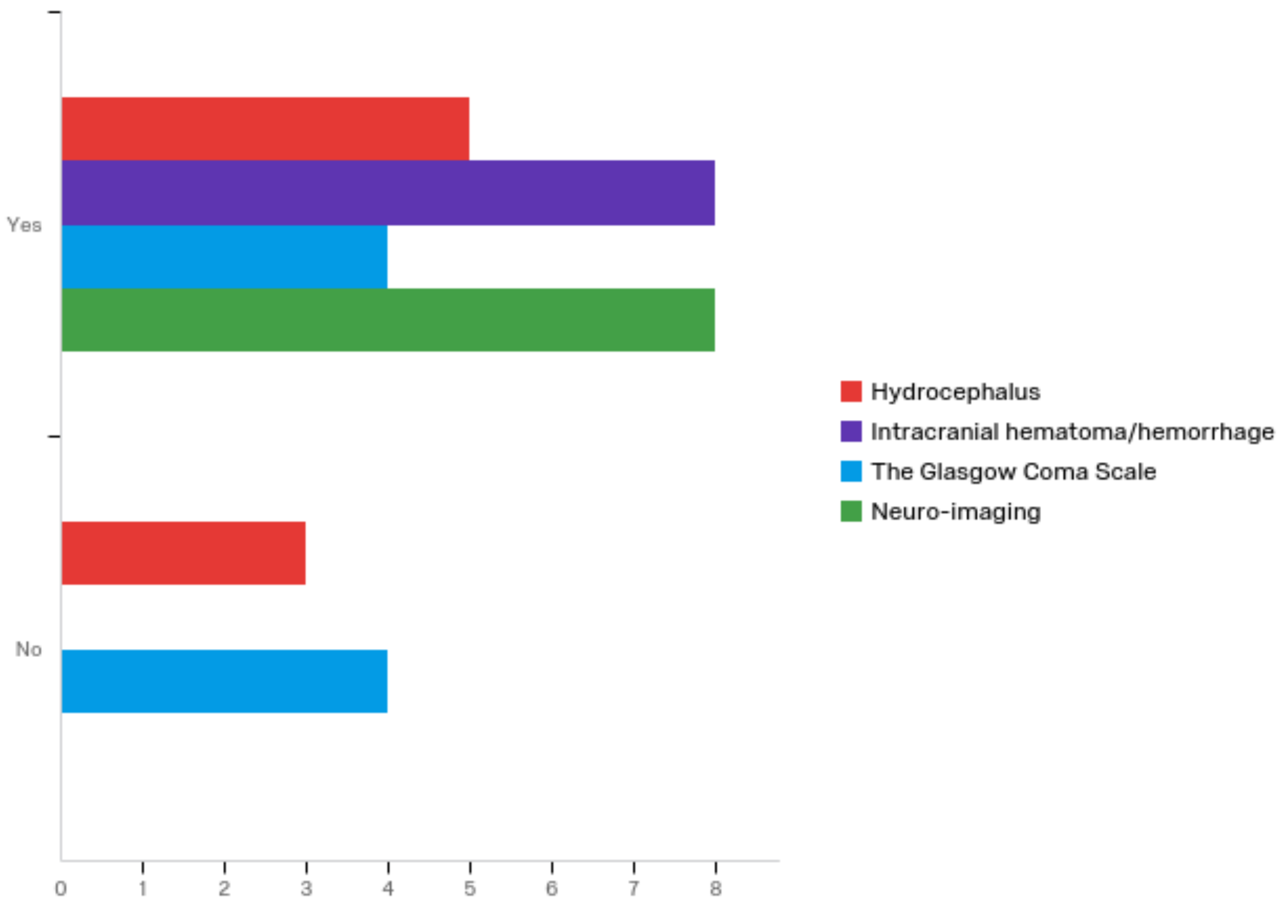
#	Question	Confident		Not confident		Total
1	The pathophysiology and treatment of hydrocephalus	12.50%	1	87.50%	7	8
2	The pathophysiology and treatment of intracranial hematoma/hemorrhage	37.50%	3	62.50%	5	8
3	Recording and interpreting the Glasgow Coma Scale score	37.50%	3	62.50%	5	8
4	Interpreting neuro-imaging (e.g. CT, MRI)	12.50%	1	87.50%	7	8

Q10 - It is essential for a clinician to have a basic understanding of...



#	Question	Agree		Neither agree nor disagree		Disagree		Total
1	The pathophysiology and treatment of hydrocephalus	37.50%	3	50.00%	4	12.50%	1	8
2	The pathophysiology and treatment of intracranial hematoma/hemorrhage	75.00%	6	25.00%	2	0.00%	0	8
3	Recording and interpreting the Glasgow Coma Scale score	62.50%	5	12.50%	1	25.00%	2	8
4	Interpreting neuro-imaging (e.g. CT, MRI)	50.00%	4	37.50%	3	12.50%	1	8

Q11 - I would be interested in brief educational videos that review and consolidate the essentials of...



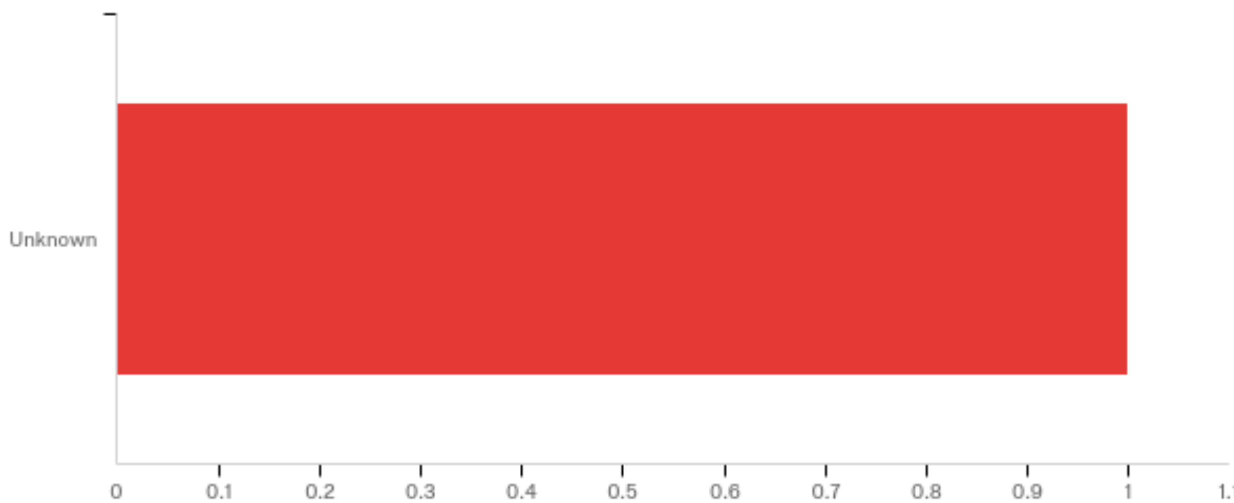
#	Question	Yes		No		Total
1	Hydrocephalus	62.50%	5	37.50%	3	8
2	Intracranial hematoma/hemorrhage	100.00%	8	0.00%	0	8
3	The Glasgow Coma Scale	50.00%	4	50.00%	4	8
4	Neuro-imaging	100.00%	8	0.00%	0	8

Q12 - Please use the space below to add any additional thoughts, or any other neurosurgical concepts on which you would like to receive more training.

Please use the space below to add any additional thoughts, or any other neurosurgical concepts on which you would like to receive more training.

The scales were too black or white - I have varying levels of comfort and confidence with these topics

Q12 - Topics



Answer	%	Count
Unknown	100.00%	1
Total	100%	1

HMS Academy (IRB) Approval Notice (13 September, 2017)

HMS Academy Approval Notice

Dear Carl Gustaf,

Your study, “Brain surgery and Asynchronous, Video-Based Learning: Increasing Neurosurgical Knowledge and Self-Efficacy in Medical Students” has been approved by the HMS Academy. If you decide to make the suggested revisions please send us a copy.

Good luck on your project.

The Academy

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The Academy at Harvard Medical School

Appendix D. Additional references

Curriculum creation and content

Greenberg MS (2010). Handbook of Neurosurgery (7th Edition). Thieme Publishers, NY, US

Samandouras G (2010). The Neurosurgeon's Handbook (1st Edition). Oxford University Press, Oxford, UK

Technology and software

Mediasite. Sonic Foundry. Accessed 2018. Mediasite Harvard Medical School. More information available at http://www.sonicfoundry.com/mediasite/

SPSS. IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.