eLearning resources to supplement postgraduate neurosurgery training

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Abstract

Background: In an increasingly complex and competitive professional environment, improving methods to educate neurosurgical residents is key to ensure high quality patient care. Electronic (e)Learning resources promise interactive knowledge acquisition. We set out to give a comprehensive overview on available eLearning resources that aim to improve postgraduate neurosurgical training and review the available literature.

Material and Methods: A MEDLINE query was performed, using the search term “electronic AND learning AND neurosurgery”. Only peer-reviewed English-language articles on the use of any means of eLearning to improve theoretical knowledge in postgraduate neurosurgical training were included. Reference lists were crosschecked for further relevant articles. Captured parameters were the year, country of origin, the method of eLearning reported, the type of article, as well as its conclusion. eLearning resources were additionally searched for using Google.

Results: Of n=301 identified articles by the MEDLINE search, n=43 articles were analysed in detail. Applying defined criteria, n=28 articles were excluded and n=15 included. Most articles were generated within this decade, with groups from the USA, the UK and India having a leadership role. The majority of articles reviewed existing eLearning resources, others reported on the concept, development, and use of generated eLearning resources. There was no article that scientifically assessed the effectiveness of eLearning resources (against traditional learning methods) in terms of efficacy or costs. Only one article reported on satisfaction rates with an eLearning tool. All authors of articles dealing with eLearning and the use of new media in neurosurgery uniformly agreed on its great potential and increasing future use, but most also highlighted some weaknesses and possible dangers.

Conclusion: This review found only a few articles dealing with the modern aspects of eLearning as an adjunct to postgraduate neurosurgery training. Comprehensive eLearning platforms offering didactic modules with clear learning objectives are rare. Two decades after the rise of eLearning in neurosurgery, some promising solutions are readily available, but the potential of eLearning has not yet been sufficiently exploited.

Key words: eLearning; electronic learning resource; resident training; new media; internet; neurosurgery; postgraduate training; education

Introduction

Few technological advances in the history of humankind have been so decisive for evolution as computer technology and the internet [34]. For neurosurgeons the internet has opened up new ways of communication and information exchange. For difficult clinical cases that two decades ago might have been discussed on the telephone between two remotely located, information exchange can now be enhanced by sending radiological images, videos or the entire medical history within seconds [34, 37], with the additional potential for remote multidisciplinary team discussions. Furthermore, there is no question that since the advent of computer and internet-based electronic(e) learning, knowledge acquisition has dramatically changed. Where closing a knowledge gap required the help of a medical librarian and a week off to browse in the 1980s, we are nowadays used to “Google” for a quick answer within less than a second [33]. For neurosurgical trainees, internet sites can offer learning resources to supplement textbooks and other aids [24]. However, the search for high quality neurosurgical information on the internet can be time-consuming, and disappointing [51]. Furthermore the integrity of the information found may not be immediately obvious.

Neurosurgical training is both science and art and it requires profound theoretical knowledge as well as adequate practical exposure to become a good neurosurgeon [2]. What is clear is that in today’s increasingly complex and competitive professional environment, training of neurosurgical residents has become a topic of utmost importance. The new generation of neurosurgeons face a difficult paradox. Modern patients are well informed about high-tech minimally invasive neurosurgical care and demand better surgical results and fewer complications [41]. In parallel, improved outcomes have to be accomplished by neurosurgeons with less experience, largely due to government-enforced working time restrictions and decreasing caseload [8, 43, 45]. While surgical training remains the most time-intensive of all specialty training [4], it is apparent that new and more effective training methods have to be employed in order to be able to compensate for the loss in exposure, as well as to meet the higher expectations [21]. The quality of training becomes ever more important, as recent data has demonstrated that better theoretical (and practical) neurosurgical training is associated with better theoretical (and practical) knowledge and skills at the end of training [44]. In the present environment, opinion leaders agree that augmented training including eLearning, cadaveric models, simulators and structured surgical education programmes are indispensable [44]. While recent reports have highlighted the role of cadaveric models, simulators [40], and structured programmes to acquire practical surgical skills [25, 42, 46, 47], the use of eLearning has not been systematically assessed [5].

Objective

This article will give a comprehensive overview of available eLearning resources that aim to improve theoretical aspects of postgraduate neurosurgical training. It will review the available literature concerning eLearning in postgraduate neurosurgical training and will also present ideas on how to implement eLearning resources in postgraduate neurosurgery training in Europe.

Material and Methods

Definition of eLearning

Learning is a change in knowledge attributable to experience [31]. eLearning has been defined as "*an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning*".

This way of learning differs in several ways from traditional methods, particularly by the use of electronic media. Whereas full eLearning approaches rely entirely on new technology, health care training usually requires a combination of traditional (hands-on skills-based training at a practical level) with computer-based self-directed eLearning methodologies, also referred to as "blended learning" [10]. For the present work, no differences have been drawn between the terms "blended learning" and "eLearning".

Study inclusion

A MEDLINE analysis was performed on August 21, 2016, using the search term "electronic AND learning AND neurosurgery". The search resulted in n=301 articles that were subsequently screened for inclusion, titles, abstracts and full-text articles were analysed for eligibility. Only peer-reviewed English-language articles on the use of any means of eLearning (as defined above) to improve theoretical knowledge in postgraduate neurosurgical training were included. We excluded articles reporting on electronic media to augment undergraduate training, postgraduate training in specialties other than neurosurgery, patient information and articles reporting on the use of modern techniques to improve practical surgical skills, such as virtual reality, cadaver, dissection or simulator training. From the identified articles on eLearning in neurosurgery, reference lists were crosschecked for further relevant articles that were also included.

Finally, a Google search was performed on August 22, 2016 using the same terms "electronic, learning (and) neurosurgery", collecting the available eLearning resources that have not been mentioned in articles referenced in MEDLINE. The first 100 search results

were screened for inclusion, aiming for websites dedicated to augmenting postgraduate neurosurgical training with eLearning. In addition, available eLearning resources personally known to the authors were added.

Collected data

Captured parameters were the year, country of origin, the method of eLearning reported, the type of article, as well as its conclusion. Types of eLearning resources were graded according to Blankstein et al. [7]

Results

Of n=301 identified articles from the MEDLINE search, n=43 articles were analysed in detail. Applying the defined criteria above, n=28 articles were excluded and n=15 included.

Table 1 provides an overview on the included articles, summarising the method of eLearning reported, as well as the main conclusions drawn from each article. It is apparent that most articles were generated within this decade, with certain leadership roles in the USA, the UK and India. The majority of articles reviewed existing eLearning resources, others reported on the concept, development, and use of generated eLearning resources. There was no article found that scientifically assessed the effectiveness of eLearning resources (against traditional learning methods) in terms of learning efficacy or costs. There was furthermore only one article reporting satisfaction rates of users with an eLearning tool [6].

Table 2 contains eLearning resources for neurosurgical postgraduate training that were identified, sorted for the level of complexity.[5, 7] Identified eLearning platforms with didactic modules and clear learning objectives are briefly presented in the following.

ebrain

ebrain is a non-profit initiative, largely supported by the Joint Neurosciences Council (JNC) and The European Academy of Neurology (EAN). It represents the world's largest, most comprehensive web-based eLearning resource in clinical neuroscience [13, 19]. The project has evolved from being UK-based to a resource that can be used by both trainees and trainers all over the globe. Currently, there are over 7500 users registered to use ebrain and the website receives about 200 – 300 hits per day (http://ebrainjnc.com) [48]. Lessons can be studied individually or in combination. Learning certificates are automatically generated and can be used within portfolios and to evidence self-directed continuing professional development (CPD; approved by the Royal College of Physicians (UK)).

It incorporates a rich array of multimedia material including over 650 interactive, multimedia-rich lessons in 25 modules, along with more than 100 webinars, virtual case reports, assessments, learning paths and bibliographies [19]. Sessions are interactive and consist of text, images, video and audio content. For example there are anatomical slides that require labelling and case histories that require the learner to make decisions. Operative clips explain how to perform operations and deal with complications. The course material includes clear objectives at the start of each lecture and a handful of multiple-choice questions at the end for self-assessment [48].

One of the features that sets ebrain apart from more traditional learning resources is its ability to be updated on a constant basis. A built-in feedback system warrants constant improvement of the sessions, should users not approve of the content [19]. This ensures continuous internal auditing and as a result provides a system for on-going development and improvement [13].

ebrain also offers trainees the possibility to participate in an online neurosurgery exam once per year. The exam consists of 100 multiple-choice questions that have to be answered within 150 minutes. The standard is roughly the same as the UK or European board examination for neurosurgery (EANS exam) and thus serves as a valuable tool to prepare. Immediately on completion, the trainee receives the score and can download a PDF certificate of participation. Shortly after completion of all exams, an analysis of scores and participation by training programme and level of training is published on the website, with participant confidentiality respected at all times.

AIIMS NETS

The All India Institute of Medical Sciences (AIIMS) Neurosurgery Education and Training School (NETS; http://aiimsnets.org) has been founded as an initiative to globally disseminate information, supplement surgical knowledge of neurosurgeons in and after training, and support networking. It is supported by the Indian ministries of Science, Technology and Health, as well as by the World Federation of Neurosurgical Societies (WFNS) trust. As a free-of-charge web-based resource, AIIMS NETS provides virtual education material in the form of a video library, webinars and tele-education material to augment theoretical knowledge in anatomy, pharmacology, pathology, radiology, neurology and surgical techniques [26]. Seminars cover the topics of vascular, skull-base, paediatric, neuro-oncology, functional, spinal, peripheral nerve, neurotrauma, miscellaneous and recent advances in neurosurgery. An exchange of comments between trainees and experienced neurosurgeons is possible. The AIIMS NETS also offers both the possibility to sign up for a

hands-on workshop and to access a page dedicated to patient education, extending the possible use of this resource to other purposes.

SCI eLearning

Valuable eLearning resources about the comprehensive management of spinal cord injury (SCI) can be obtained at http://elearnsci.org free of charge after registration. This web-based resource has been established by the International Spinal Cord Society (ISCoS), funded by Access to Healthcare, filling an information gap for health care professionals involved in SCI.

The content has been developed by an international panel of over 300 leading SCI experts, reflecting knowledge that is important in both high and low resource countries. Modules, each consisting of various sub-modules, are addressed to specific disciplines including physicians, nurses, physiotherapists and social workers. For physicians, topics include pre-hospital care, clinical assessment, management of vertebral fractures, respiration, nutrition, bladder and bowel-care, sexuality and fertility after SCI, also covering pain, psychosocial and further specific aspects of SCI (infections, spasticity, paediatric SCI, aging with SCI, cell transplant therapy, etc.) [9]. The sub-modules contain in-depths webinars, followed by the possibility of self-assessment. References for further reading are provided. Despite this site containing high quality information, its content only covers a small area of neurosurgery.

Discussion

This review of the literature found only a few articles dealing with modern aspects of eLearning as an adjunct to postgraduate neurosurgical training. Most of the identified articles reported merely some of the aspects of eLearning, such as internet presentations of scientific journals and neurosurgical organisations or smartphone applications. Comprehensive eLearning platforms offering didactic modules with clear learning objectives were rare, but three could be identified: 1) ebrain (http://ebrainjnc.com), 2) AIIMS NETS (http://aiimsnets.org) and 3) SCI eLearning (http://elearnsci.org). All authors of articles dealing with eLearning and the use of new media in neurosurgery uniformly agreed on its great potential and increasing future use, but most also mentioned some of its weaknesses and possible dangers. Two decades after the rise of eLearning in neurosurgery [34], some promising solutions are readily available, but the potential for eLearning is not yet sufficiently exploited.

Why eLearning?

In 2009, Mayer has nicely summarised what should be known about the theory behind learning [31]. Knowledge construction requires *active cognitive processing* of information and is less likely to occur by passive learning. The *dual channel* theory suggests the separate processing of verbal and visual material, and the principle of *limited capacity* tells that only small amounts of information can be processed in each channel at any time. Multimedia-enriched eLearning material (e.g., a webinar) impinges on the ear and the eye. It is held briefly in the verbal and visual sensory memory before some of the content is transferred to the working memory, mentally organised to form a verbal and pictorial model and finally integrated into previous knowledge and stored in the long-term memory. As compared to traditional learning by reading a textbook, multimedia-enriched eLearning resources help learners to understand more deeply [31].

Different types of eLearning: Pros and Cons

Advantages and disadvantages of each type of eLearning are summarized in the following:

1. Listservs are (at best large) electronic mailing lists that allow a defined group of people (listserv members) to discuss topics, concepts, and problems that are pertinent to the group. Listservs provide a forum for faculty and trainees and depend solely on the experience, knowledge and motivation of the group members. Formal modes of assessment are usually lacking. Despite their frequent use, the risks of this type of eLearning include low participation rates and low levels of moderation and information filtering [50]. Models such as “Surginet” have been developed for general surgery [18] but without any large impact on neurosurgery to the best of the authors knowledge. Listservs in the field of neurosurgery are summarised in table 2.
2. Blogs (including micro-blogs e.g. Twitter) may contain neurosurgical topics and neurosurgeons who subscribe to one or several of these blogs can receive the latest news in the field. Blogs are frequently offered by the most important neurosurgical journals that use this means to distribute recent abstracts among the neurosurgical community. Some blog authors allow readers to comment, enabling a direct exchange and dynamic discussion [27].
3. Social media platforms (e.g. Facebook) were originally developed to foster inter-personal non-professional exchange, but most systems have increasingly been recognised as useful for professional networking. By joining neurosurgical groups and communities within these social media platforms, news can be shared and discussed but confidentiality concerns makes discussion of individual cases inappropriate [5].
4. Smartphone applications contain information including basic neuroanatomy, relevant scoring systems such as the Glasgow Coma Scale and can give support in evidence-based decision-making. Apps may help a trainee by giving detailed step-by-step

instructions on numerous medical procedures accompanied by high-resolution video and images (e.g. lumbar puncture, central venous lines, etc.), explain how to interpret plain x-rays, CT or MRI scans and give help on drug dosing and interactions [21]. Some of the apps helpful for neurosurgical training are summarised in table 2. Many of the available apps have recently been reviewed [54].

5. Online libraries are the most traditional and most commonly used form of eLearning. They were started by turning textbooks into e-textbooks by simply scanning and storing this information (books, notes, slides and additional material). Subsequently, they were enriched by hyperlinking text so that a learner could jump to another section or call up a glossary [10]. These libraries today provide an important method for medical personnel to improve access to all kinds of multimedia resources. A rich collection of neurosurgical videos of sometimes excellent quality (e.g., the Rhoton collection) can be found on websites such as http://youtube.com. The weaknesses of online libraries are the open-ended approach (no timeline with defined learning objectives). In addition, trainees need to identify relevant information themselves from a wealth of material, which may pose difficulties. Online libraries are widely used for the academic purposes of writing articles or searching for specific information (e.g., preparing a surgical case for the next day).
6. Modular courses and webinars are structured topic-based modules for delivering information and enable an objective-driven continuous learning experience. Modular courses have been developed by several neurosurgical organisations, such as by the American Association of Neurological Surgeons (AANS) [1] to provide “convenient, easily accessible courses in the core cognitive curriculum of neurosurgery” [7]. Courses may be followed by a quiz to test if the learning objectives have been reached. In Europe, the European Association of Neurosurgical Societies (EANS) has created a large multimedia library (EANS academy; http://academy.eans.org/) to store congress and course presentations, web- and video podcasts and learning quizzes that enables their members to access this information. Online courses and webinars make information available online, but weaknesses are the lack of official supervision or mentorships. The inability of trainees to directly interact with the faculty has been identified as a cause of reduced satisfaction with this type of eLearning [11].
7. Structured online courses deliver education directly, using the layout of a formal course with defined faculty and trainee participants, start and end times, as well as curriculum. Geographic barriers are removed, and physical classrooms replaced by simulated “face-to-face” classrooms using sophisticated software solutions (course management systems) [7]. Despite being a promising concept, especially for regions

with less educational infrastructure in neurosurgery, some of the present systems are still in their infancy.

eLearning in general: Pros and Cons

For postgraduate training, most eLearning resources are internet-based and both their advantages as also drawbacks have been described [53].

The benefits of eLearning include the 24/7 availability of the material, permitting saving on training time, travel and learning infrastructure (classrooms, etc.). Learning can be scheduled when most appropriate for the trainee such as on a quiet night shift. Consistency of eLearning content standardises learning objectives among a wider group of users with essential information for neurosurgery trainees being made easily available. Built-in feedback systems incorporated into eLearning tools ensure regular evaluation, progress and high quality standards with continuous optimisation of the resource [33]. Real-time testing and review of the content by external specialists is required.

It should be acknowledged that the quality of eLearning depends both on its content and the way it is structured. It is essential to give learners access to carefully designed resources that are limited in length [30]. The available amount of open-source data and information on the internet can be burdensome, providing an endless number of resources to review without guaranteed quality. Not sifting the “wheat” from the “chaff” may be counter-productive, with ill-written or poorly evidenced articles possibly misguiding more than helping trainees [21]. A computer, tablet or smartphone is required, which may be a limiting factor in some regions with fewer resources, although in Europe generally this is not a problem. Some trainees find learning on screens tiring, and discipline is required for effective self-directed learning. As with traditional learning resources, excellent motivation of each individual learner is required to prevent skimming through the e-learning material without proper knowledge acquisition [53].

Pertaining less to comprehensive eLearning platforms but more to the general contemporary use of electronic media in patient care (including teaching), a critical word concerning protection of privacy seems necessary. When patient data, including images or even videos, are transferred to colleagues/trainees for a second opinion/teaching purpose, we should be well aware that this data might be stored on servers in Europe or elsewhere. Physicians must use safe ways of data handling, whenever possible, to respect privacy and fulfil the confidentialness in the patient-physician relationship.

Efficacy of eLearning on postgraduate neurosurgery training

It is currently impossible to estimate the impact or efficacy of eLearning on postgraduate neurosurgical training, as no studies have been identified to assess this using a scientific

approach. Thus, data from other medical fields and undergraduate training was analysed: In 2004 a systematic review of continuous medical education (CME) by eLearning concluded that CME by eLearning was just as effective in knowledge transmission as traditional formats.[52] One year later, in the field of general medicine, n=97 primary care physicians were randomly assigned to an internet-based CME intervention or to a traditional face-to-face CME workshop. Both interventions produced similar and significant immediate and 12-week knowledge gains. The authors concluded that appropriately designed eLearning resources could produce sustained knowledge gains, comparable or even superior to those of traditional learning methods [17]. Similar results have been reported for radiation oncology [36], occupational [20], dental [3], and critical care medicine [12], psychosomatics and psychotherapy [14] and hand surgery [32]. A systematic review from 2014 on eLearning in pharmacy education concluded that it effectively increases knowledge of physicians and students. However, there was no evidence that eLearning effectively improved skills or professional practice, and the need for long-term studies following on from knowledge gain was pointed out [39]. In undergraduate medical training, a 2014 systematic review including 4955 students found that eleven out of 33 studies testing knowledge gains found higher gains in the eLearning groups. The remaining 22 studies found similar results or did not test for differences [38]. The same work described higher skill gains in eight out of thirteen studies in the eLearning groups (the remaining five studies did not detect any differences) [38]. Only very recently it was shown in a systematic review that eLearning showed either greater or similar effectiveness compared with both no intervention and non-eLearning intervention in general surgery training [28]. Extrapolating from other medical fields and undergraduate training, eLearning is likely to be an effective tool in postgraduate neurosurgery training, however without proven superiority over more traditional learning resources. Well-designed studies that compare learning effectiveness of eLearning resources with more traditional resources in the field of neurosurgery are needed to allow arriving at a final conclusion.

Satisfaction with eLearning

Except for a single report,[6] we found no studies looking at satisfaction with eLearning in the field of neurosurgery. In postgraduate residents in surgery, medicine, gynaecology and obstetrics high initial scepticism concerning eLearning (76.4%) was contrasted by high satisfaction rates after the eLearning experience (64.8%) and the majority of residents rated eLearning as better than traditional learning methods (61.8%) [23]. The above-mentioned randomised study among primary care physicians revealed similarly high satisfaction rates for eLearning and traditional learning methods, which is in agreement with most of the literature on this topic [39]. A large study with several thousand Scottish trainees reviewed

the use of eLearning modules over an academic year. The feedback was mostly positive and its flexible format suited the trainees' working environment [49].

Global potential of eLearning

eLearning has the potential to lessen the educational resource gap between the developing and developed worlds and to help fulfil the longstanding hope of improved neurosurgical knowledge and care, regardless of place of citizenship [7]. Challenges that remain, however, are the availability of free or affordable high-quality eLearning resources (AIIMS NETS is free; ebrain is free to World Bank low income/HINARI countries), the lack of computers and stable internet connections [21] and the difficulties of offering hands-on courses complementing theoretical eLearning modules. Most eLearning resources are in English, but not all learners in developing countries have sufficient English skills. Additional barriers are due to cultural differences with ethical, moral and religious issues that may arise [7].

Formative versus summative potential of online learning resources

European and US jurisdictions have well-established summative systems for assessing, regulating and licensing of neurosurgical specialists. These systems, which are rightly carefully controlled and standardised, include for example examinations, regulated training programmes and specialist registers. The systems are summative and are generally overseen by national licensing authorities. This is not the domain of eLearning.

The best eLearning systems are formative, aiming to support self-directed development and they rely on the motivation and drive of the individual learner. The ebrain examination provides a good example of this approach where examinees are fully able to “cheat” by looking up all the answers but doing this will deprive the examinee of the ability to judge how they stand in relation to their peer group. Whilst certainly not encouraged, a “cheating” examinee is of course, participating in a highly educational activity. It is our experience that very few, if any, examinees look up the answers as they do the exam but many do look up the answers straight after they finish.

As a result of the loose controls around eLearning it is critically important that regulatory (summative) and educational (formative) systems are kept entirely separate. Whilst participation can perhaps be used as evidence of learning activity, eLearning scores are not sufficiently robust to inform summative assessment.

Implications for the future training of European neurosurgeons

Neurosurgery training requires both theoretical and hands-on skills-based training at a practical level. In the setting of a standardised postgraduate neurosurgery training programme in Europe, interesting concepts of “blended learning” arise [10].

A possible application could be a schedule of eLearning objectives for each postgraduate year (PGY), as defined by the JRAAC (Joint Residency Advisory and Accreditation Committee) of the EANS and the European Union of Medical Specialists (UEMS) Section of Neurosurgery, to ensure continuous postgraduate education. For each PGY of training, eLearning modules could be assigned, with certificates of completion being awarded on achievement of the learning objectives. These certificates might then be required before a learner can participate in a practical course that follows each yearly module of increasing complexity. In PGY 1, for example, theoretical modules about the basic principles of neurosurgery, anatomy and techniques such as placing of a ventricular catheter, lumbar puncture or central venous line could be followed by a neurosurgical "boot camp", following the US and UK models [16]. For PGY 2, an eLearning module containing lumbar degenerative disc disease could be followed by a hands-on cadaveric course to perform and learn surgical approaches to the lumbar spine. For higher PGY, eLearning modules on cerebrovascular neurosurgery could be followed by a craniotomy course covering approaches to the vascular system, and so forth. Simulator training sessions of high quality might be incorporated in each year's practical course [15].

By this "blended learning" approach, concepts reviewed in the eLearning sessions could be applied and transformed into practical knowledge. A standardised and certified entry level of knowledge in trainees after the eLearning phase would ensure broad participation in the practical part of the training and promote equivalent knowledge between trainees from different European countries [43]. In addition to the well-established EANS training courses, the proposed concept has the potential to maximise cooperation within the European neurosurgical community, using both a standardised eLearning tool and the local strengths of the European training sites in their ability to offer cadaveric courses, simulation and virtual reality training [15]. The model follows the idea of a European curriculum of contemporary neurosurgical knowledge [44]. The same endeavours are recorded in the US [35] and UK [22] but we are well aware that surgeons, including neurosurgeons, are mostly conservative regarding educational hierarchies and pedagogy [16]. We hope that visionary medical educators that are in positions to influence the future direction of postgraduate neurosurgery training in Europe see the potential of eLearning. Available resources can be exploited for the benefit of neurosurgical trainees, and be further developed to meet all desired requirements, if considered valuable.

Limitations

Despite a systematic approach, the search might have failed to identify further relevant articles. Also, as this article was drafted, existing eLearning sources may have been changed and new eLearning resources may have been generated. In an open-source medium such

as the internet, it becomes a challenge to provide a comprehensive collection of available information. Cost-effectiveness of eLearning is relevant but the necessary information is not available and the ratio of cost to benefit cannot be analysed. Also, no standardized quality assessment was performed, as heterogeneity of included studies was substantial. For undergraduate training, reports have indicated a reduction of costs from the use of blended learning, with cost benefits starting after the first year of transition. This is largely due to the staffing requirements of traditional forms of learning [29].

Conclusion

eLearning may be a useful resource in postgraduate neurosurgery training, but at present no data proves its efficacy or superiority above traditional learning methods. Just like non-electronic teaching methods it has its strengths and weaknesses. When used appropriately, eLearning could help to standardise learning and support a common European curriculum of contemporary neurosurgical knowledge. However, theoretical training is not enough, and a combination of eLearning with practical hands-on cadaveric and / or simulator courses is required. Visionary medical educators are required to make sure the eLearning possibilities at hand are exploited and developed to their full potential.

Conflict of interest:

MNS, HC, VL and ST are Clinical Leads for ebrain but have no financial conflict of interest to declare.

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Figure legends:

Figure 1: Screen-shot of the ebrain browser-interface.

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Table 1: Included articles, sorted after the year of publication.

Reference	Country of origin	Method of eLearning reported	Type of article	Conclusion
Pareras and Martin-Rodriguez, 1996 [35]	Spain	Internet-based neurosurgical resources	Literature review	• Technical developments will change medicine • Increased computer and data transmission capacity will support the remote visit, video-conferences, surgical simulation or even remote virtual surgery.
Bernad et al., 1998 [6]	Romania	Electronic internet-based textbook on neuro-ophthalmology	Report of experience	• Resource contains theoretical information and clinical cases as examples in neuro-ophthalmology • Educators and learners at a neurosurgical department reacted positively • This type of web-based eLearning resource is a promising tool for the future of neurosurgical training
Thomson and Phillips, 2003 [54]	UK	Internet-based resources for neurosurgery and neuropathology	Literature review	• Internet-based revolution in medical informatics is going to change the way that neurosurgery and neuropathology are practised • Patient information about their conditions and the available treatments will improve • Physicians must learn to accept this new technology and use it to its full potential
MacDonald, 2005 [28]	USA	Collection of web-based online tools	Progress report	• Tools have been developed for the benefit of the public and the neurosurgical community • The CNS has designed and compiled these features with the objective of making them easily accessible and integral part of neurosurgical education and practice
Blankstein et al., 2011 [7]	Canada, Ghana, USA	Listserv, online library, webinar, online course	Literature review and proposition of concept	• eLearning resources can help create a more self-sustainable environment for neurosurgical training • They can serve to fill the contact gap with the developing world
Hughes and Brennan, 2011 [21]	UK	Internet and smartphone applications	Literature review	• Internet offers a vast array of opportunities to access information and learn, and its role will increase in the future • Volume and lack of regulation of the information has the potential to overwhelm; ascertaining quality, veracity and usefulness is required • Enhanced access must not compensate for a

				decline in accuracy
Chhabra et al., 2013 [35]	India, international consortium	Modules on spinal cord injury (SCI) including case studies, expert interviews, questions, photos, videos	Progress report	• There is limited access to up-to-date SCI training and learning material • Web-based free-of-charge education resource was built in order to bridge this gap • It addresses educational needs of all disciplines involved in the management of SCI • It comprises seven modules, each consisting of various submodules that cover a specific topic and include a presentation, activity-based learning, references and questions
Prasad and Kumar, 2013 [38]	India	Web resources on Neurology and Neurosurgery and its allied subjects	Literature review	• Internet represents a new revolution in the realm of human communication; extending the power of humans by means of technology • Neuroscientists make increasing use of national and international cooperation by new communication technologies • The global and all-pervasive instant electronic interaction of the next generations will radically change methods of communication in neuroscience
Sheehan et al., 2013 [44]	USA	Self-Assessment in Neurological Surgery (SANS)	Research article	• The SANS spine examination demonstrated knowledge gaps in specific categories for spinal surgeons • Areas of diminished performance differed between spinal and general neurosurgeons
Thomson, 2013 [53]	UK	E-learning platform for clinical neuroscience (ebrain)	Literature review	• ebrain is an electronic platform offering a broad variety of eLearning material for clinical neuroscience, including o Certificated sessions enriched by images o Video and audio o Case histories that require taking decisions o Operative clips (surgeries and how to deal with complications)
Fontes et al., 2014 [16]	USA	Online material made available for neurosurgical “boot camp” for PGY 1 residents	Progress report	• Neurosurgical “boot camps” for PGY 1 residents to standardise teaching of basic skills are broadly accepted and effective • Hybrid between online course material and practical hands-on courses is increasingly required for residents before starting clinical activities
Jotwani et al., 2014 [26]	India, Germany	Web-based learning platform (presentations, operative videos,	Research article	• eLearning platforms provide up-to-date educational content that make them a fast and easy-to-use resource • eLearning will save unnecessary expenditures

		lecture videos, 3D-animation videos, social network, questions and answers forum, tele-education)		of time and travel for neurosurgical trainees, especially helpful to those in the developing parts of the world
Sheehan et al., 2014 [45]	USA	Self-Assessment in Neurological Surgery (SANS)	Research article	• SANS revealed significant knowledge gaps that appeared to be more common in certain areas of neurosurgery (e.g. vascular) and to varying degrees both in residents and practicing neurosurgeons • Identifying and addressing knowledge gaps is important
Barbosa Pereira et al., 2015 [5]	Brazil, Netherlands	E-learning by Blogs, Facebook, Twitter, Linkedin	Literature review	• Various tools to allow internet-based learning in neurosurgery have been created • They have to be used with care, especially regarding accuracy and reliability
Skovrlj et al., 2015 [46]	USA	Neurosurgery residency websites	Research article	• Neurosurgery residency websites are an invaluable source of information and critical guide for medical students applying to neurosurgery residency • Content and usability of websites could be optimized

Table 2: Identified eLearning resources for neurosurgical postgraduate training. Uniform resource locators (URLs) correct on 25 August 2016. The list is not exhaustive, and a multitude of further resources are available. The present selection is based on quality, currency and ranking in a search engine (see methodology of search).

Type of eLearning resource	Access / URL	Description
Listservs		
Neurosurgic	http://www.neurosurgic.com	Professional networking site for the neurosurgical community.
Neurological Surgery Research ListServ	http://www.surgicalneurology.org	International group of over 700 members sharing knowledge and building contacts in neurosurgical care.
Neurolist	http://www.neurolist.com	Discussion list on neurological or neuropsychological topics.
Child neurolist	http://www-personal.umich.edu/~leber/c-n/e-mailUM.html	Deals with clinical and research topics in paediatric neurology and neurosurgery.
Discussion lists in Neuroscience	http://www.cerebromente.org.br/lists_i.htm	Website that provides a list of Listservs for various topics in neuroscience.
History of Neuroscience Forum	http://lists.ucla.edu/cgi-bin/mailman/listinfo/histneur-l	Discussion forum on any aspect of the history of neuroscience.
NIH neuroscience email list	https://neuroscience.nih.gov/neuroseries/EmailList	email announcements about NIH neuroscience seminars.
Blogs		
Neurosurgery Blog	http://www.neurosurgery-blog.com	Daily bibliographic and video review.
Neurosurgery Blog – more than just brain surgery	http://www.neurosurgeryblog.org	To investigate and report on how healthcare policy affects patients, physicians and medical practice, to illustrate the art and science of neurosurgery.
Neurosurgery Blog by @neurocirurgiabr	http://neurocirurgiabr.com	About 7000 followers on news relevant to the neurosurgical community.
Neurosurgery Blog	http://weillcornellbrainandspine.org/Neurosurgery-blog	News relevant to the neurosurgical community, featured by the Weill Cornell Brain and Spine Center.
Columbia neurosurgery blog archive	http://www.columbianeurosurgery.org/category/blog/	News relevant to the neurosurgical community, featured by the University of Columbia neurosurgery department.
Smartphone applications		
Neuromind.cc	http://blog.digitalneurosurgeon.com	App containing commonly used grading and classification systems to help in clinical decision-making. Free of charge.
Neurosurgery Survival Guide	http://neurosurgerysurvivalguide.com	App covering basics, common procedures of neurosurgery, neurocritical care, paediatric

		neurosurgery and TBI, amongst others. About 6 US-Dollars.
Pocket Brain	https://itunes.apple.com/us/app/pocket-brain/id508820653?mt=8	Neuroanatomy tool to navigate in 3 dimensions through the meningeal layers, sub-cortical structures into the ventricles. Cross sections and nerve pathways are available. About 5 US-Dollars.
Helsinki Microneurosurgery Basics and Tricks	https://itunes.apple.com/us/app/helsinki-microneurosurgery/id506365864?mt=8	Contains the eBook "Helsinki Microneurosurgery Basics and Tricks", enriched with videos and pictures. Free of charge.
iSpineCare	https://itunes.apple.com/us/app/ispinecare/id348144361?mt=8	Covers spine anatomy, function and disease. Library of anatomical visualisations, spine pathologies, medical images and educational notes. About 60 US-Dollars.
Neuro Toolkit	https://itunes.apple.com/us/app/neuro-toolkit/id350656519?mt=8	Contains commonly used Neurology and Neurosurgery grading scales, some of them helping to estimate prognosis. About 5 US-Dollars.
Online libraries		
Journal of Neurosurgery	http://thejns.org	Some free abstracts, Neurosurgical Focus offers free-access articles
NEUROSURGERY	http://journals.lww.com/neurosurgery/	Free abstracts
Journal of Neurology, Neurosurgery and Psychiatry	http://jnnp.bmj.com	Free abstracts
Acta Neurochirurgica	http://link.springer.com/journal/701	Free abstracts
SPINE	http://journals.lww.com/spinejournal/	Free abstracts
Surgical Neurology International	http://surgicalneurologyint.com	Free-access articles
Neurosurgical Clinics of North America	http://www.neurosurgery.theclinics.com	Free abstracts
Global Spine Journal	https://www.thieme-connect.de/products/ejournals/issue/10.1055/s-005-28831	Free-access articles
The Spine Journal	http://www.thespinejournalonline.com	Free abstracts
European Spine Journal	http://link.springer.com/journal/586	Free abstracts
Child's Nervous System	http://www.springer.com/medicine/surgery/journal/381	Free abstracts
British Journal of	http://www.tandfonline.com/toc/i	Free abstracts

Neurosurgery	bjn20/current	
NCBI Pubmed	http://www.ncbi.nlm.nih.gov/pubmed	Index of most relevant scientific articles published within the last decades
Youtube	https://www.youtube.com/results?search_query=Neurosurgery	Video lessons on various topics, e.g. neuroanatomy or surgical technique.
The human brain – atlas of the human brain	http://thehumanbrain.info	Nicely illustrated atlas of the macro- and microscopic human brain anatomy
Web-based surgical simulators and medical education tool	http://vmg.cs.bangor.ac.uk/Sim/	Placing a ventricular catheter, treating trigeminal neuralgia, pedicle screw insertion, lumbar puncture, central venous line, etc.
Interactive Atlases: Digital Anatomist Project	http://vertex.biostr.washington.edu/da.html	Anatomical diagrams and quizzes
Anatomy.tv	http://www.anatomy.tv	Three-dimensional anatomical models
Whole brain atlas	http://www.med.harvard.edu/AANLIB/	MRI of normal and pathological brains
The Merck Manual	http://www.merckmanuals.com/professional	Medical textbook covering neurological diseases
Medscape Neurosurgery	http://www.medscape.com/resource/neurosurgery	Information on neurosurgical diseases and their treatment
Modular courses and webinars		
EANS academy	http://academy.eans.org/	Webinars and video podcasts, ePosters, PDFs, abstracts and learning quizzes, EANS annual scientific meeting recordings
SBNS eLearning	http://www.sbns.org.uk/index.php/education-and-training/elearning/	The SBNS refers to ebrain as their eLearning portal (see below)
AANS eLearning	http://www.aans.org/Education%20and%20Meetings/Online%20Resources.aspx	Online (CME) courses, webinars, the Rhoton online repository, neurosurgical videos, link to Neurosurgical Focus, the Journal of Neurosurgery Mobile App, AANS annual scientific meeting recordings
CNS eLearning	https://www.cns.org/education/browse-type/online-learning	Webinars, on-demand library, CNS annual meeting recordings
ESPN eLearning	http://www.espneurosurgery.org/e-learning	Webcasts, e-Posters, ESPN annual meeting recordings
AOSpine eLearning	https://www.aofoundation.org/Structure/education/Pages/education.aspx	Evidence-based eLearning modules, videos, Apps, online repository
Structured online courses		
ebrain and espine	http://www.ebrainjnc.com http://espine.org.uk	Electronic platform offering a broad variety of eLearning material for clinical neuroscience, including certificated sessions enriched by images, video and audio, case histories that require taking decisions,

		operative clips on surgeries and how to deal with surgical complications.
All India Institute of Medical Sciences (AIIMS) Neurosurgery Education and Training School (NETS)	http://aiimsnets.org	Web-based learning platform, including downloadable presentations, operative videos, didactic lecture videos, 3D-animation videos, social network, questions and answers forum, tele-education
SCI eLearning	http://www.elearnsci.org	Modules on spinal cord injury including case studies, expert interviews, questions, photos, videos

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On these learning pathways pages we have provided links to selected, recommended content from within the e-brain sessions. Learning pathways for trainees have been constructed around the curricular. Learning pathways for specialists are designed to bring sessions from different places in the curriculum together in one place.

If you feel there are other groups who could benefit from a learning path page please contact support@ebrainJNC.com.

Topic 1

Surgical Principles

Click on the links below

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Diagnosis and Management of Post-operative Haematoma

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