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D.E.S. Chirurgie Vasculaire

IS IT USEFUL TO CREATE 3D CLINICAL-BASED ANATOMICAL TEACHING PROGRAMS IN SURGICAL RESIDENCY?

EST-IL UTILE DE CRÉER UN PROGRAMME D'ENSEIGNEMENT D'ANATOMIE 3D POUR L'INTERNAT DE CHIRURGIE ?

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List of abreviations

RV	Virtual reality
3D	3 dimensions
ENT	Otorhinolaryngology
MCQs	Multiple-choice questions
AKIVI	Anatomical Knowledge In Virtual Immersion
TOS	Thoracic outlet syndrome

Plan

TITLE: "IS IT USEFUL TO CREATE 3D CLINICAL-BASED ANATOMICAL TEACHING PROGRAMS IN SURGICAL RESIDENCY?"

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ABSTRACT

Background.

Current virtual reality (VR) technology allows for the creation of instructional video formats that incorporate three-dimensional (3D) stereoscopic footage. Combined with 3D anatomic dissection, any surgical procedure or pathology can be represented virtually to supplement anatomical learning and surgical preoperative planning. We have created a standalone VR, web and mobile app that allow trainees to learn surgical anatomy via a dedicated teaching program.

Methods. A prospective case-control study was completed to evaluate the impact of virtual reality anatomical teaching. After a prerequisite anatomical knowledge assessment, participants were randomized in two-groups: stereoscopic anatomical teaching program versus classic teaching of thoracic brachial outlet syndrome and its related anatomy with anatomical and surgical books. Then, students completed a written anatomical test to assess their basic knowledge in vascular anatomy. Pre- and post-test performances were analyzed with independent t-tests for total score assessing basic anatomical knowledge, anatomical relationships and clinical inference. Afterwards a French national survey of vascular surgery residents was carried out using a 5-point Likert scale evaluation form. It evaluated the pedagogical needs in the vascular surgical anatomy curriculum from the students point-of-view.

Results. Before performing the teaching, the 20 students included were homogenous in term of total exam note in abdominal aorta (mean 78,78% vs 76,34%) and carotid artery evaluations (mean 78,57% vs 74,76%). After the course, there were statistical difference ($p<0,05$) between the stereoscopic 3D video group (n= 10, 90%) and classical teaching group

concerning the total exam note, descriptive anatomy, anatomical relationships and clinical inference skills. All the students thought this method (accessible on mobile, computer and virtual reality headsets) seemed indispensable to their anatomical training course (100%). Among 56 residents (50% of total French vascular surgery residents), most felt that there is a lack of educational resources in surgical anatomy for residents entering vascular surgery residency (69,6%). All agreed that a surgical anatomy teaching program certified by clinicians and anatomists is needed (100%).

Conclusions. The teaching video with 3D stereoscopy seems to be a useful and complementary teaching tool useful that is approved by the residents themselves. In a future study, it will be necessary to evaluate the contribution of this teaching in the long term and the possibility of integrating it into the vascular surgeon curriculum worldwide.

INTRODUCTION

Human anatomy is one of the fundamental disciplines of medical studies. Its teaching combines lectures, dissections and commented illustrations and texts since the sixteenth century and the work of André Vésale[1]. 500 years later, teaching this specialty is a delicate undertaking. Almost all of the anatomical learning is provided in the early stage of the medical curriculum[2]. The students learn the basics without any clinical and surgical experience. At the beginning of residency, a second anatomical course is required to learn and practice surgery, such as vascular surgery. This includes a refresher course on surgical and clinical based-anatomy.

The recent growth of digital technologies offers new perspectives for medicine and the clinical follow-up of patients[3,4], surgeries and surgical anatomical teaching[5,6]. Students can now view videos in 3D with their smartphones. The use of 3D stereoscopy is better than 2D to stimulate the student's visuospatial cognition[7,8] and to learn anatomy[910]. We have shown in a previous study that this technology help medical students to better understand anatomical relationships and clinical inference[2]. The ability for students to visualize in 3D anywhere enables us to offer digital anatomo-surgical course tutorials on the go and challenge previous ways of accessing anatomical knowledge. In order to provide anatomically correct certified videos, we undertook their production with residents, anatomical and vascular teachers. These videos have been added as an extra tool to traditional teaching methods since 2016 at the University of Angers. The objective of this study is to evaluate the pedagogical value of 3D stereoscopic video compared to traditional study method during residency.

To learn surgical anatomy, residents need to assist senior surgeons as often as possible. The repetition allows him/her to increase his/her mental representation of the surgery. Then, he/she can learn in the anatomical and/or simulation center and perfom surgeries step-by-step with the help of an attending over a period of time. This teaching method is good, and many surgeons have been successfully trained this way. However it has its limits, such as the need to find a “mentor”, to be in a reference university center for rare entity or to attend conferences with hidden costs. Moreover, the increase of the number of residents accepted in the vascular surgery residency program raises the training issue, when surgeries are scarce (too many residents for few surgeries). As a result, we have developed an anatomo-surgical 3D teaching program that can be displayed in a dedicated virtual reality, mobile and web-application. This application can be used in a pre-operative context. The aim of this study was to compare this approach to a traditional teaching method.

METHODS

Study design and population

This study is a prospective study conducted between September 2020 and June 2021. The study population is composed of surgical residents from the University of Medicine in Angers and Nantes (France). All participating residents received anatomical instruction and dissection study during their medical curriculum.

Before the start of the session, the residents were divided into 2 main groups by randomization in order to minimize selection bias. The "video group" learnt from a 3D stereoscopic video and the "traditional methods group" or "book group" studied a selection of reference books.

3D stereoscopic clinical based anatomical video

A 3D video with French commentary was developed to teach the anatomy of the thoracic brachial outlet, explaining its syndrome and its surgical treatment (available at https://vimeo.com/manage/videos/569900021, supplemental video material 1). It could be watched via a 3D television, smartphones or virtual reality headsets in a dedicated VR, mobile and web app (AKIVI, Anatomical Knowledge in Virtual Immersion[11]). We set up a pedagogical committee to provide anatomical content that met the requirements of the first years of vascular surgery training. A resident (AD, first author) was also involved in the creation of this pedagogical resource at each step to meet students and teachers requirements.

Study protocol

Before the teaching session, both groups completed an anatomical quiz to evaluate their knowledge of vascular surgical anatomy (Supplemental material 2, 3, 4, 5, 6 and 7). Then, the students in the video group answered questions about the thoracic brachial outlet (supplemental material 8, 9 and 10) after viewing the dedicated instructional video. The students in the book group answered the same questions but after reading a selection of reference books[12–14]. The video group also completed a satisfaction questionnaire about the 3D experience. This quiz was not mandatory for the students. By agreeing to take it, the students agreed to participate in the study. Each student was evaluated individually.

3D students feedback

After watching the video, the students in the video group completed a 5-point Likert scale evaluation form ("Not agree at all", "rather disagree", "don't know", "agree" and "totally agree"). They also had the opportunity to select positive and negative aspects of the video.

Pre- and post-course testing

This pedagogical approach aims to help students achieve the acquisition of anatomical knowledge and understanding of vascular anatomy and its surrounding structures. The quiz consisted of several multiple-choice questions (MCQs). According to the pedagogical committee, three key skills had to be evaluated: fundamental knowledge, structural relationships in space and clinical and surgical relevance. The same quiz on the above topics was given to both groups. For each group, an average score out of 100 was calculated for each question, as well as the percentage of correct answers.

Several precautions were taken to minimize possible bias in the analysis: (A) all data were collected using designated serial numbering without any identifying information; (B) all exams were analyzed by an anatomist who was not involved in the teaching phase of the study, did not know the students and was unknown to the student's designated group. Data analysis was performed in SPSS (version 17.0). Paired t-tests were used to compare pre- and post-test performance. Between-group performance and demographic comparisons at baseline were analyzed using independent t-tests. A p-value of less than 0.05 was considered significant.

French national survey of teaching needs for surgical anatomy

An ancillary survey was carried out to evaluate the teaching needs for vascular surgical anatomy using a google form questionnaire. It was sent to vascular surgery residents in France to evaluate teaching needs. Survey questions were available electronically through the Google Form® website and remained open for responses from January to August 2021. Residents who are members of the *Société Française de Chirurgie vasculaire* were informed of the survey via email. Participation was voluntary and not remunerated. Responses were collected as a single best answer, or as all applicable answers from a drop-down list of options, or as free text. The online survey tool had the ability to identify duplicate responses, which were not included in the data analysis. The data analysis was conducted in SPSS (version 17.0). Descriptive statistics were presented in the form of frequencies and percentages.

Role of funding source

The AKIVI project was supported by University of Angers' Health Department and its 3D-lab, the Pays de la Loire department council and SATT ouest valorisation. This funding made possible the production of the videos and the creation of the application.

RESULTS

1. Prospective case-control study

1.1. Population

A total of 20 residents were enrolled in the study (figure 1) and successfully completed the course in the laboratory of Angers, France. All participants were surgical residents. All completed the study and followed up. The video group and books group were each composed of 10 residents who completed the first cycle of medical studies in different French universities. They were residents in different surgical specialties. Among the residents in the video group, there were 6 males and 4 females from Angers (n=3), Nantes (n=1), Marseille (n=1), Paris, (n=1), Caen (n=1), Toulouse (n=1), Amiens (n=1) and Reims (n=1). In this group, there were two vascular surgery residents (2nd and 3rd year), two visceral surgery residents (2nd and 3rd year), one maxillofacial surgery resident (1st year), one ophthalmology resident (1st year), two orthopedics surgery residents (1st and 5th year), one ENT surgery resident (4th year) and one urological surgery resident (1st year). Among the book group, there were 5 males and 5 females from Angers (n=2), Nantes (n=1), Paris (n=2), Rennes (n=1), Poitiers (n=1), Caen (n=1), Toulouse (n=1) and Bordeaux (n=1). In this group, there were two vascular surgery residents (two in 1st year), two thoracic and cardiovascular surgery residents (1st and 3rd year), two visceral surgery residents (2nd and 3rd year), one neurosurgery resident (1st year), one gynecology-obstetrics resident (4th year), one ENT surgery resident (2nd year) and one urological surgery resident (2nd year).

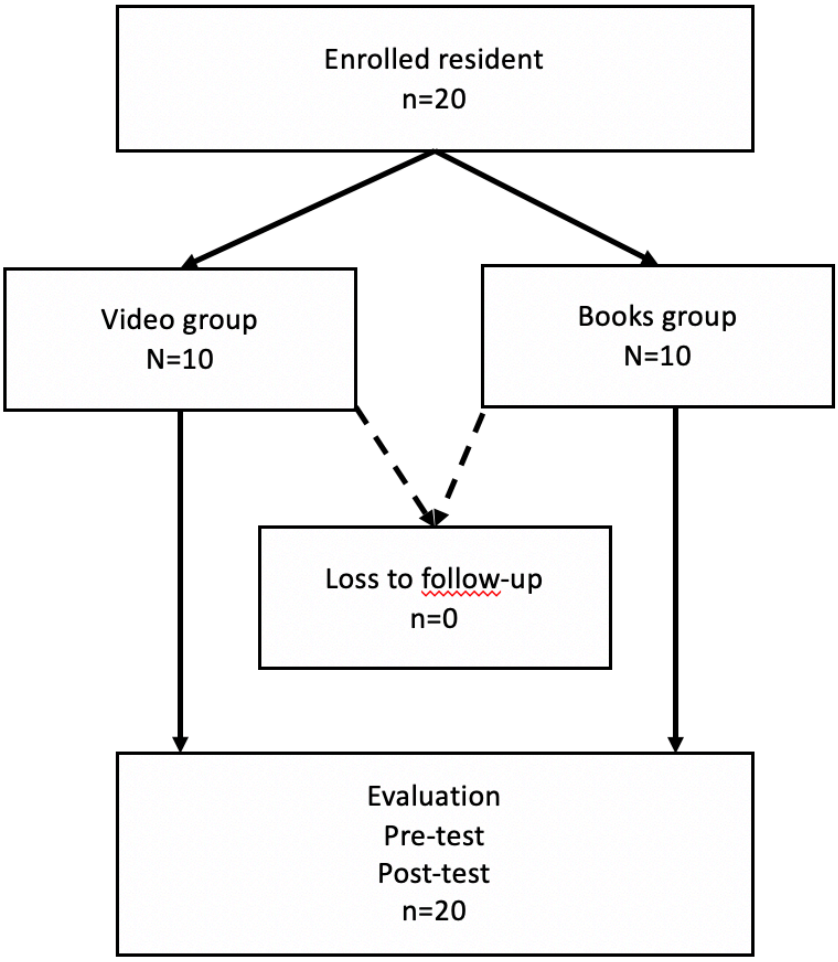

Figure 1: Cohort recruitment flowchart

1.2. Educational evaluation

Before taking the course there were no statistical difference in abdominal aorta knowledge in terms of total score (78,8% vs 76,3%, p=0,162), descriptive anatomy (mean 81,3% vs 71,3%, p=0,293), anatomical relationships (mean 82,9% vs 74,3%, p=0,112), clinical reasoning (mean 63,3% vs 61,7%, p=0,41) between the video and book group, respectively (table I). Before taking the course there were no statistical difference in carotid artery knowledge in terms of total score (78,6% vs 74,8%, p=0,162), anatomical relationships (mean 77,0% vs 78,0%, p=0,569), clinical reasoning (mean 74,2% vs 70,0%, p=0,298) between the video and book group, respectively (Table I).

Table I : Group performance concerning abdominal aorta and carotid artery before instructional video or books. For each group, expression of the average score out of 100 then the average of the correct answers in percentage. This table demonstrates the group test performances before their exposure to the instructional video or books.

SUBJECT	**KNOWLEDGE EVALUATED** (MEAN OF GOOD RESPONSES)	**PRE TEST VIDEO GROUP**	**PRE TEST BOOKS GROUP**	**P-VALUE**
CAROTID ARTERY	**Descriptive anatomy (Q1-Q10)**	**87,0%**	**74,0%**	**p = 0,028**
	Anatomical relationships(Q11-Q30)	**77,0%**	**78,0%**	**p = 0,569**
	Reasoning, physiopathology, clinical outcomes (Q31-Q42)	**74,2%**	**70,0%**	**p = 0,298**
	TOTAL	**78,8%**	**74,8%**	**p = 0,162**
ABDOMINAL AORTA	**Descriptive anatomy (Q1-Q15)**	**81,3%**	**71,3%**	**p = 0,293**
	Anatomical relationships(Q16-Q29)	**82,9%**	**74,3%**	**p = 0,112**
	Reasoning, physiopathology, clinical outcomes (Q30-Q41)	**63,3%**	**61,7%**	**p = 0,412**
	TOTAL	**78,8%**	**76,3%**	**p = 0,162**

After taking the course there were statistical differences (p<0,05) between the video group and books group in terms of the total score (mean 90% vs 70,67%): descriptive anatomy (mean 90% vs 69,33%), anatomical relationships (mean 74% vs 54%), and clinical reasoning (mean 98% vs 81%) of thoracic brachial outlet (Figure 2).

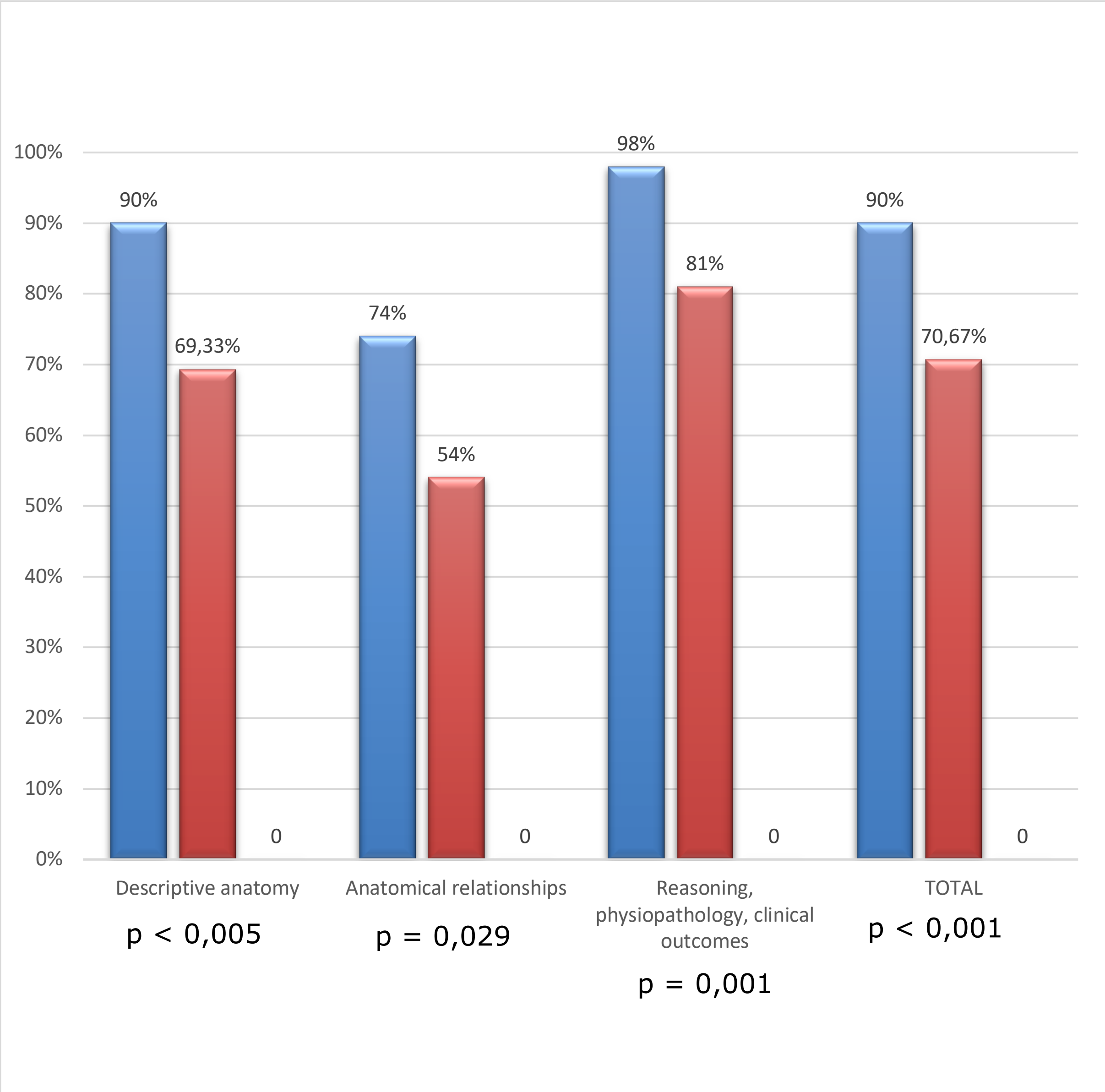

Figure 2: Post-test groups performances concerning thoracic brachial outlet. Blue, video group; Orange, books group.

1.3. Satisfaction questionnaire

Regarding the residents who viewed the video of the thoracic brachial outlet and who answered the satisfaction questionnaire (n=10) (table II), results are summarized in table III. According to the Q1-Q2 responses, all of the residents thought that the video was an easy method to use (100%, table III) and close to practice. According to all residents, the possibility of reviewing the videos (100%, Q3, Table III) and seeing dissections outside the anatomical laboratory (100%, Q4, Table III), especially in 3-dimensional stereoscopy, was useful. Observing the relationships and depth between organs was positive (100%, Q5, Table III). Moreover, students enjoyed the ability to watch the surgery with commentary from the surgeon's point of view (100%, Q6, Table III). Students did not give negative feedback after watching this tutorial course.

All the students thought that providing digital certified course using currently available devices (smartphone, computer and virtual reality glasses) seem indispensable to their anatomical training course (100%, Q7, Table III). They thought they learned more with the help of the 3D video than during previous practical dissection work (100%, Q8, Table III). However, almost half of the residents thought that this kind of video could not replace cadaver dissection (40%, Q9, table III).

Table II: Evaluation criteria for the video by residents using a Likert Scale

Q1	Do you find this teaching method easy to use
Q2	Does this teaching method seem similar to practicing it according to you
Q3	The possibility of reviewing the videos is a positive aspect of this method
Q4	The possibility of seeing dissections outside an anatomy laboratory is a positive point of this method
Q5	The possibility to see 3-dimensional dissections and to see the relationships and depth between organs is a positive aspecy of this method
Q6	The ability to see the surgery with commentary from the surgeon's point of view is a positive aspect of this method
Q7	Does this method (visible on mobile, computer, virtual reality glasses) seem indispensable to you in your anatomical training course
Q8	"I learned more with the help of the 3D video than during the practical dissection work dissection".
Q9	"I preferred virtual visualizations to cadaver dissections".

Table II: Evaluation of the 3D stereoscopic video by the residents (n=10).

	Not agree at all	Rather disagree	Do not know	Agree	Totally agree	Positive reviews
Q1	0%	0%	0%	0%	100%	100%
Q2	0%	0%	0%	50%	50%	100%
Q3	0%	0%	0%	0%	100%	100%
Q4	0%	0%	0%	0%	100%	100%
Q5	0%	0%	0%	0%	100%	100%
Q6	0%	0%	0%	30%	70%	100%
Q7	0%	0%	0%	40%	100%	100%
Q8	0%	0%	0%	60%	40%	100%
Q9	10%	30%	10%	50%	0%	50%

2. National survey of teaching needs in vascular surgical anatomy

A total of 56 vascular surgery residents answered the questionnaire (Table IV). All residents felt that learning anatomy is fundamental for vascular surgery (100%; Q1, Table V). Most residents felt that there was a lack of educational resources in surgical anatomy for students entering vascular surgery residency (69.6%) and that these resources were insufficient (69.6%; Q2, Table V). Regarding the resources that residents use on a daily basis to learn surgical anatomy, the majority responded that they used anatomy books (87.5%), followed by operating room experience (66.1%) and dissections (25%). The vast majority of residents believe that their undergraduate and postgraduate teaching does not prepare them to the level required for a vascular surgery resident (85.7%; Q3, Table V) in terms of anatomy. All residents thought that using 3D dissection views would be useful for learning anatomy (100%, Q5, Table V) as well as using radiographic views (94.7%; Q7, Table V). All residents said that they would use the app as a digital complement to the surgical anatomy curriculum (100%; Q4, Table V) with a progressive surgical anatomy teaching (100%, Q6, Table V) and certified teaching videos (100%, Q8, Table V). Almost all residents agree that this teaching should be part of their specialized teaching curriculum with national and/or international harmonization (98.2%; Q9, Table V).

Table IV: Assessment of teaching needs in surgical anatomy among vascular surgery residents in France.

Q1	Do you feel that learning anatomy is fundamental to vascular surgery
Q2	Do you feel that the resources available are sufficient and appropriate for your level
Q3	Would you say that your undergraduate and postgraduate teaching prepares you anatomically to the level required for a vascular surgery resident
Q4	If a digital supplementary teaching program for surgical anatomy was offered to you, would you use it
Q5	Do you find the use of 3D dissection views useful for learning anatomy
Q6	Would you say that a progressive surgical anatomy teaching pathway would be useful to you
Q7	Do you find using radiological views useful for learning anatomy
Q8	Is the accuracy (and certification) of the teaching videos, both anatomically and surgically, important
Q9	Would you like this teaching to be part of your specialized teaching curriculum (national/international harmonization)

Tableau V: Evaluation of the teaching needs in surgical anatomy among vascular surgery residents in France.

	Not agree at all	Rather disagree	Do not know	Agree	Totally agree	Positive reviews
Q1	0%	0%	0%	0%	100%	100%
Q2	10,7%	58,9%	0%	28,6%	1,8%	30,4%
Q3	32,1%	53,6%	0%	14,3%	0%	14,3%
Q4	0%	0%	0%	28,6%	71,4%	100%
Q5	0%	0%	0%	26,8%	73,2%	100%
Q6	0%	0%	0%	33,9%	66,1%	100%
Q7	0%	5,4%	0%	42,9%	51,8%	94,7%
Q8	0%	0%	0%	32,1%	67,9%	100%
Q9	0%	1,8%	0%	32,1%	66,1%	98,2%

DISCUSSION AND CONCLUSION

In this study, we have shown that vascular surgeon residents are in favor of a virtual clinical-based anatomical teaching program and that they would find it useful. Vascular surgery residents felt that they did not have enough teaching resources for surgical anatomy despite its importance in their training. Since sustainable improvement of teaching is the aim of our project, future goals should include expanding the use of 3D digital video tutorials as a complementary resource for other anatomical areas, and evaluating its long-term benefits on learning.

All the interviewed vascular surgery residents were in favor of a digital additional teaching program in surgical anatomy. They agree with the addition of certified virtual tutorials.to 3D dissection views and radiological views to enhance their learning. There is a significant need for students to have resources in surgical anatomy to better integrate and understand the prerequisites for simulation and surgical practice[15]. For residents, the learning of surgical techniques requires to visualize in 3 dimensions the anatomy of the operated region and to follow the of senior surgeons when operating[16,17]. Anatomy is the cornerstone of medical training. It is one of the fundamental sciences and part of the core curriculum. Sometimes considered as as set in stone, new pedagogical methods allow for changes in its teaching and making it more interactive[19]. Integrating anatomical, clinical, physiological and pathological aspects to its teaching has helped increase its profile among student cohorts.

In our study, before the course (video or books) there were no statistical differences ($p>0,05$) between the groups performances in basic vascular anatomy. After watching the tutorial, we have seen that the 'video' group scored higher than conventionally taught students in descriptive anatomy, anatomical relationships and even clinical inference. These results are similar to another study conducted on a different population[15]. Understanding anatomy is being able to master visual-spatial skills. However, these skills are not necessarily mastered nor understood by the students pre-specialisation, especially for specific topics such as the thoracic brachial outlet that include three anatomical regions (interscalene triangle, costoclavicular space, pectoralis minor space[20,21,22]) to which we can add the humeral block[23,24].

Over the years the anatomical and surgical knowledge of the thoracic outlet has evolved. Therefore, it is necessary to provide an updated anatomical and surgical description of each area. As an example, we will discuss thoracic outlet syndrome (TOS). Peet et al1 first used the term thoracic outlet syndrome in 1956 to describe the constellation of symptoms caused by compression of the neurovascular bundle at the level of the thoracic outlet. Roos first described its surgical treatment in 1966 using the transaxillary approach[25]. TOS is a disease that requires a good anatomical knowledge[24] to understand its diagnosis and its surgical treatment. This syndrome is a good example of the implication of anatomical knowledge in relation to surgical technique.

In the clinical-based anatomical videos, the addition of a surgical section showing the view of the main surgeon during the operation allowed for a better understanding of the surgical relevance of such anatomy. Our results showed that the instructional video with stereoscopic 3D views is an effective tool for learning surgical anatomy and the steps of a surgical procedure. Although the acquisition of theoretical knowledge is essential, the mastery of surgical procedures is the cornerstone of clinical expertise[26]. The teaching of surgical skills is one of the most important and exhilarating tasks for a university surgeon[27]. All teaching programs are aiming at professional skills acquisition, which is the "Individual's capacity to effectively resolve various problems met in his domain of practice" [28]. The clinical skill in vascular surgery, as in other surgical specialties, is multi-dimensional. It requires the cognitive capacity to collect relevant clinical data, to resolve problems, to reason clinically and to show empathy towards patients and as said before, technical psychomotor skills[27]. Most of this surgical learning is done in the operative room on real surgeries during residency. It follows 3 stages: demonstration- repeated practice- immediate feedback on the procedure[29]. The first stage (demonstration) is the main one and is progressively put aside in favour of the next ones (practice and feedback). This kind of teaching is obviously dependant on the day-to-day mentoring. Students need to be taught by their attendings in order to develop and acquire the technical skills for surgical procedures. This "buddy-system" is limited by the centre's habits, specialties, and the inevitable affective link between the attending and his/her student [30]. Furthermore, the surgical disciplines tend to be over specialized and with numerous new technics, instruments that are complementary or alternative to conventional procedures, it multiplies the ways to teach surgery. This progressive direction towards poles of excellence or even hyper-specialization is a trend that is widespread among institutions. The specific care needs of local populations and the frequent medical under-staffing of university teams accentuate the phenomenon.

As 50% of the residents argue, the training program using only educational videos with a 3D method cannot obviously replace the cadaver dissection course. As described previously[2], surgical anatomy training deserves a further exploration into the role of synergistic multimodal teaching strategies, such as the combination of 3D anaglyphic stereoscopy with virtual reality simulations, augmented reality teaching and 3D printing. In our study, students supported the development of stereoscopic teaching as a complementary resource. Indeed, their enthusiasm for the 3D method was mitigated by the fact that they found this approach did not exclude the traditional pedagogical method. These findings were in accordance to previous studies, where new digital tools and integrative teaching methods have been promoted to complement anatomical education and the lecture experience [31,32]. Modern digitalized methods of teaching anatomy are undoubtedly useful[3334]. However, body dissections can still benefit significantly new medical students, and these procedures should be maintained as part of surgical training[35]. 3D stereoscopic based learning, and new techniques such as virtual reality and 3D printing can be used to enhance and support anatomical teaching and learning in medical education[36]. According to Papa and Vaccarezza's review[37], we are confident that gross anatomy through dissection and mental visualization cannot be undermined in a modern medical curriculum, since it gives a 3D experience that cannot yet be reproduced by the most advanced digital anatomy programs available.

In our study, we evaluated the contribution of an educational video on an uncommon surgical approach (axillary removal of the first rib) performed in a tertiary center. This surgery requires an excellent anatomical knowledge. The contribution of educational videos including 3D stereoscopic views at the beginning of the residency could help beginning residents to understand this surgical procedure. It could also allow residents who are not part of an expert center to access training on specific surgical techniques. Scientific societies work hard to digitalize and promote such teaching. Vascular surgery training in France is delivered by the French College of Vascular Surgery at national level. During their four years of residency, vascular surgery residents must follow a national digital teaching programme (SIDES-NG). The SIDES NG platform is the result of work carried out in collaboration with all the national stakeholders concerned by the 3rd cycle of medical studies. This platform is supported by all French medical universities. This represents more than 40,000 residents, 44 postgraduate diplomas and 34 faculties of medicine[38]. The postgraduate diploma in vascular surgery, includes distance learning courses taught by different surgeon-teachers of the specialty in France. Slide shows are accessible to the residents and are divided into 3 parts (base phase, deepening phase and consolidation phase) in line with the new reform of the 3rd cycle of medical studies. The viewing of these videos could be part of the validation of the different phases of the postgraduate diploma in vascular surgery and amounts to several hours of viewing. Currently, the foundation phase includes a chapter on anatomy and surgical approaches in vascular surgery and it should be noted that the anatomy of the thoracic brachial outlet and surgery for resection of the first rib are not included in this teaching. Moreover, it does not include 3D stereoscopic video or VR courses. In view of this new digital curriculum, the addition of educational videos of surgical anatomy could be a complement to the digital training of vascular surgery residents.

Limitations

Our study has several limitations. Our sample size was small, despite the recruitment of residents from several hospital sites and several surgical specialties. However, we do not believe that this limits the generalization of the results. They should not vary according to the geographical origin of the students given that they received anatomical training in different French medical schools. Surgical specialty is not a determining factor either, as the answers to the MCQs were equivalent for both groups before viewing the video or the anatomy books.

Descriptive results showed that the resident profile was heterogeneous in terms of surgical specialty, age, vascular surgery experience and university origin. Whatever the student profile, all students assume that a complementary anatomo-surgical program is needed.

CONCLUSION

The teaching of vascular anatomy and surgical approaches in postgraduate vascular surgery studies is essential. The development of educational videos using 3D stereoscopy in particular could complement teaching in this field. This digital clinical-based method of anatomical teaching is particularly suited as a complement to traditional teaching methods. In the future, we propose to evaluate the impact of this teaching method on the long-term knowledge of the student during the next classes of the French College of Vascular Surgery with the aim of harmonizing the anatomical residency teaching worldwide.

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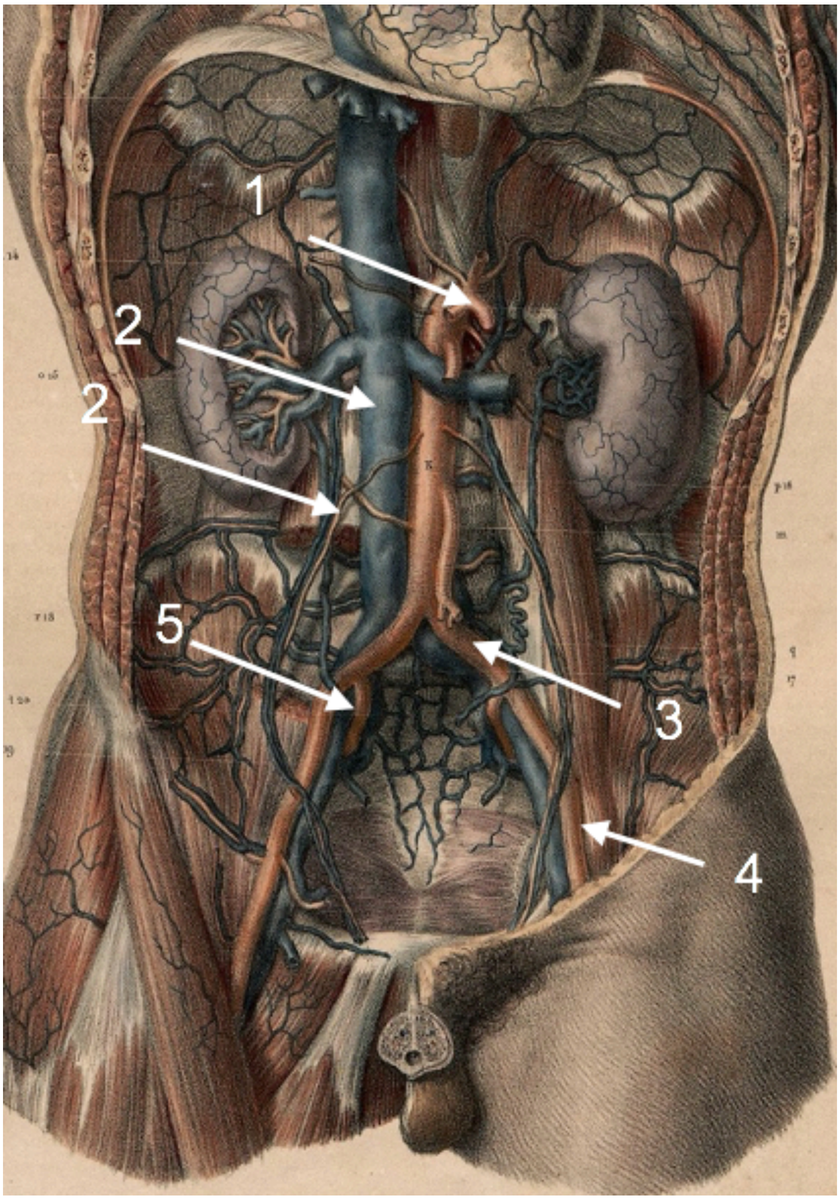
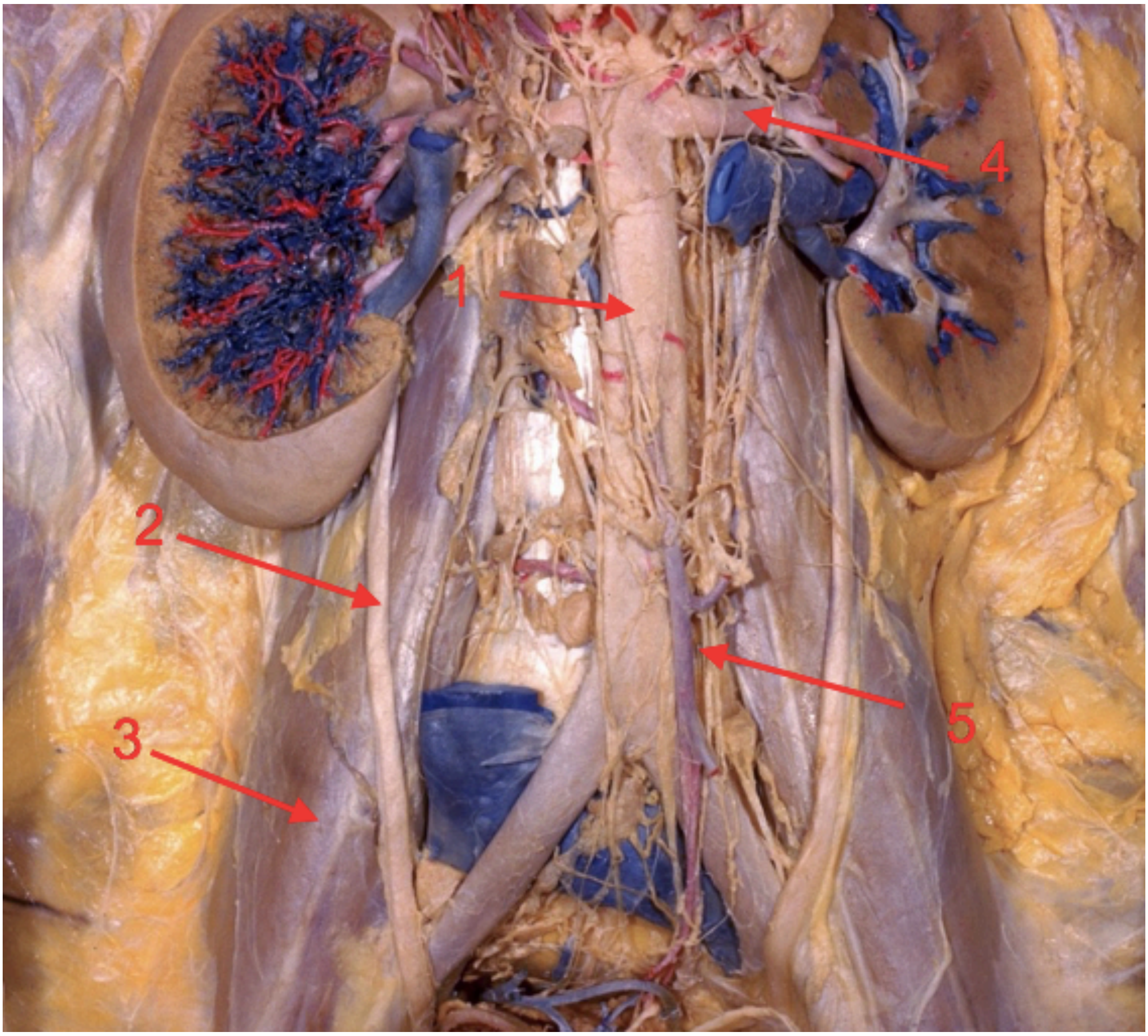
Supplemental video 1: Thoracic brachial outlet anatomical video (2D version for reviewing available at https://vimeo.com/manage/videos/569900021). Residents watched a 3D stereoscopic version of this video during this study.

Supplemental material 2: Anatomical view of abdominal aorta (Q1-Q5). Illustration for Traité complet de l'anatomie de l'homme comprenant la médecine opératoire (1831-1854) by Jean-Baptiste Marc Bourgery. Public domain.



Supplemental material 3 : Anatomical view of abdominal aorta (Q6-Q10) from David Lee Basset stereoscopic Atlas. Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License.

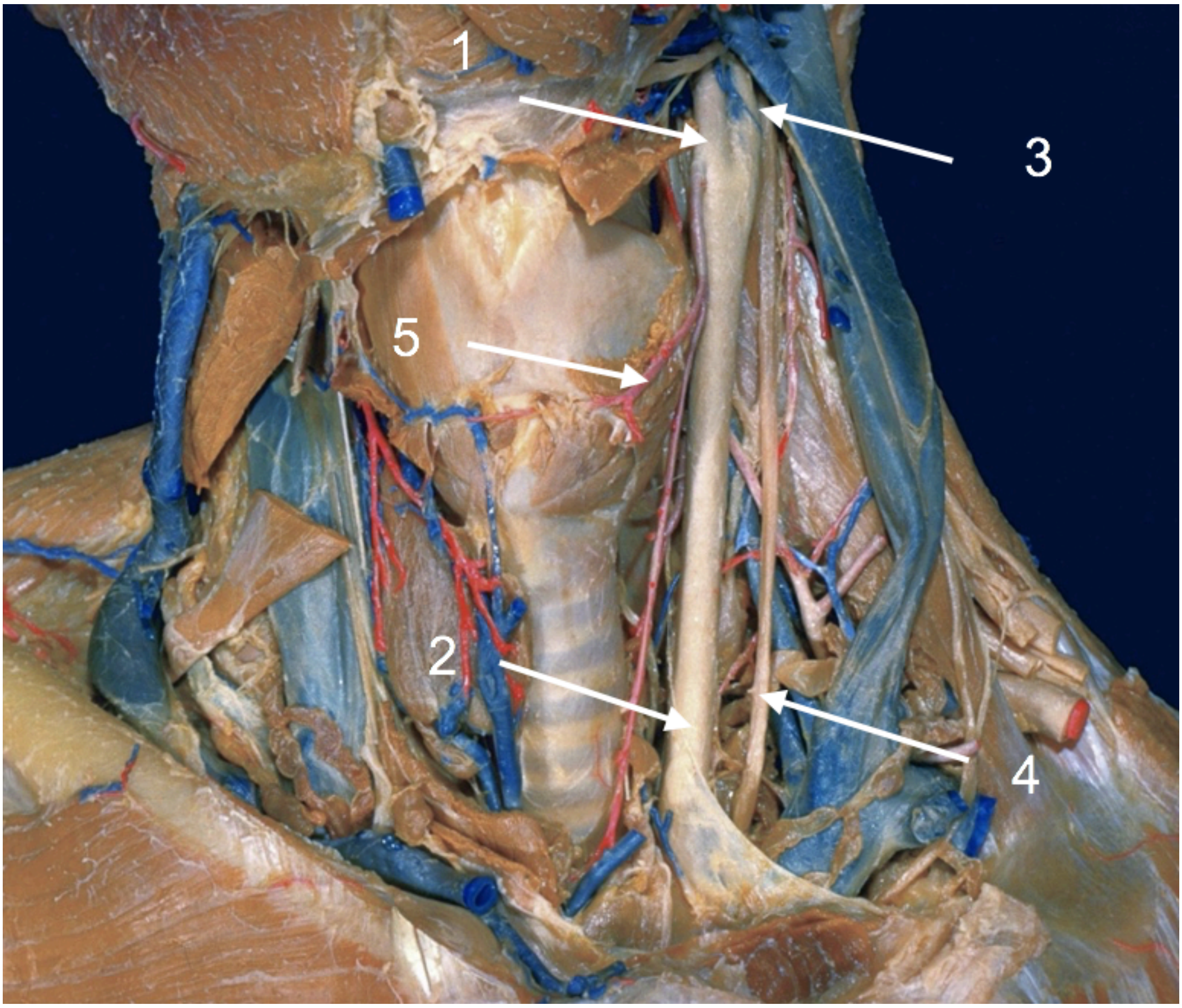


Supplemental material 4: Anatomical evaluation of abdominal aorta. R/W: right wrong items

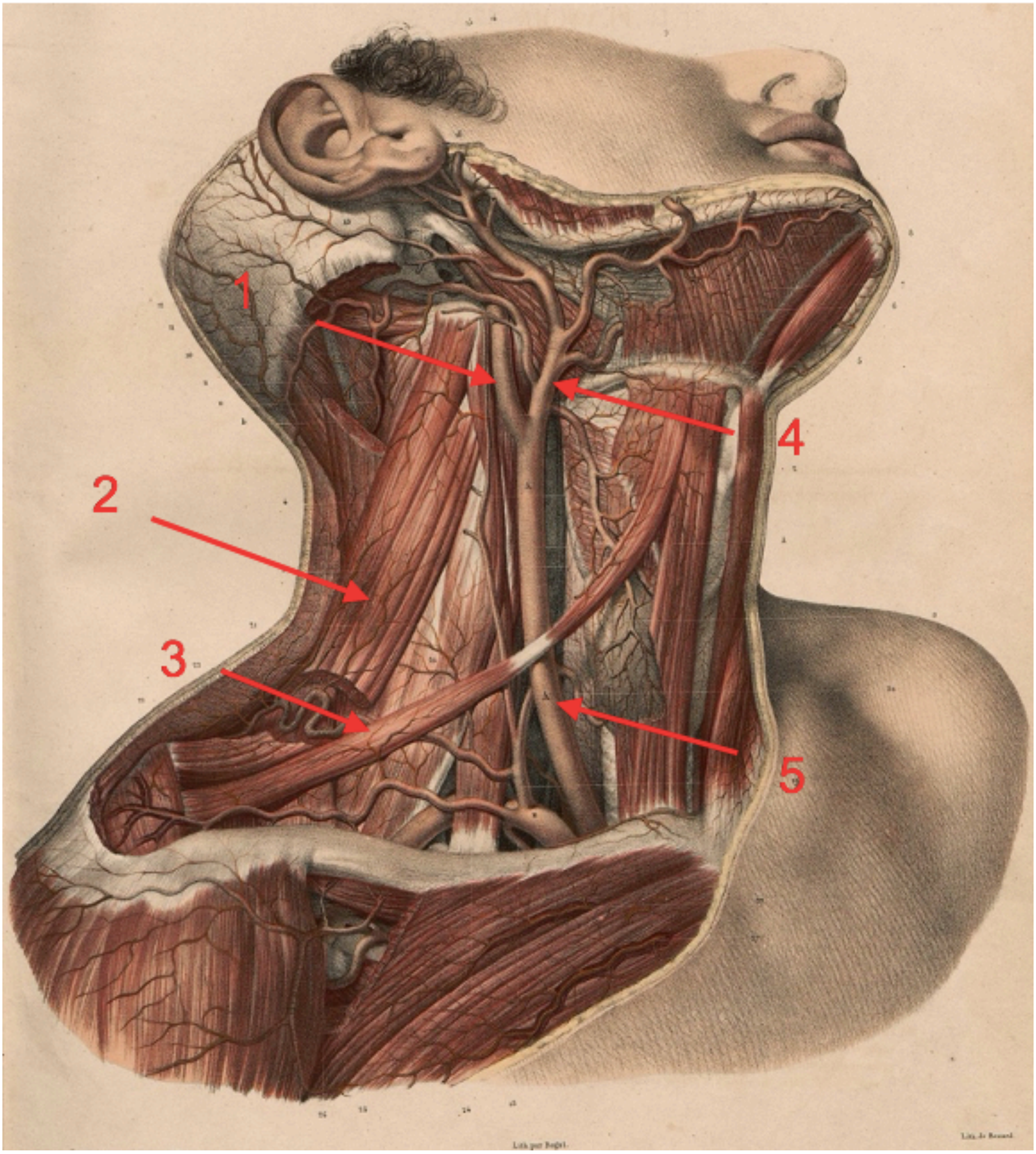
Knowledge evaluated	Questions	Type
Descriptive anatomy	Q1 – Legend 1 = Celiac trunk	R/W
	Q2 – Legend 2 = Inferior vena cava	R/W
	Q3 – Legend 3 = Left Primitive Iliac Artery	R/W
	Q4 – Legend 4 = Left internal iliac artery	R/W
	Q5 – Legend 5 = Right external iliac artery	R/W
	Q6 - Legend 1 = Sub-renal aorta	R/W
	Q7 - Legend 2 = Urethra	R/W
	Q8 - Legend 3 = Iliac muscle	R/W
	Q9 - Legend 4 = Left renal artery	R/W
	Q10 Legend 5 = Inferior mesenteric artery	R/W
	Q11 - The abdominal aorta gives rise to parietal, visceral and urogenital collaterals.	R/W
	Q12 - The subrenal abdominal aorta gives rise to the lumbar arteries.	R/W
	Q13 - Each common iliac artery divides into an internal iliac artery and an external iliac artery.	R/W
	Q14 - The external iliac artery vascularises the pelvic viscera.	R/W
	Q15 - The inferior phrenic arteries are collaterals of the subrenal abdominal aorta.	R/W
Anatomical relationships	Q16 - The aorta enters the abdomen at the level of the T12 vertebra.	R/W
	Q17 - The abdominal aorta is retroperitoneal and follows the right edge of the vertebral bodies.	R/W
	Q18 - The abdominal aorta divides, at the level of the L4 vertebra, into the common iliac arteries.	R/W
	Q19 - The median sacral artery arises at the level of the subrenal abdominal aorta termination.	R/W
	Q20 - The celiac trunk arises at the anterior aspect of the abdominal aorta above the superior mesenteric artery.	R/W
	Q21 - The celiac trunk gives three branches: hepatic artery, splenic artery and left gastric artery.	R/W
	Q22 - The superior mesenteric artery arises at the posterior aspect of the abdominal aorta.	R/W
	Q23 - The inferior mesenteric artery arises from the anterior aspect of the abdominal aorta at the level of the L5 vertebra.	R/W
	Q24 - The arcade of Riolan is an anastomotic network between the superior mesenteric artery and the inferior mesenteric artery.	R/W
	Q25 - The renal arteries arise on the lateral aspect of the abdominal aorta on either side in L1.	R/W
	Q26 - They have a generally horizontal course, slightly oblique downwards and outwards.	R/W
	Q27 - The gonadal arteries arise on the anterolateral aspect of the abdominal aorta above the renal arteries.	R/W
	Q28 - The sub-renal abdominal aorta passes in front of the anterior common vertebral ligament.	R/W
	Q29 - Both the kidneys and the subrenal abdominal aorta are in a retroperitoneal position.	R/W

Reasoning, physiopathology, clinical outcomes	Q30 - Surgery on the subrenal abdominal aorta requires opening the root of the mesentery to mobilise the intraperitoneal contents	R/W
	Q31 - The suprarenal aorta approach is more complex as it requires approaching the duodenopancreatic block via the retroperitoneal route	R/W
	Q32 - Aortic prosthesis in the management of a subrenal aneurysm can lead to phrenic artery ischaemia resulting in ventilatory failure	R/W
	Q33 - The approach to the sub-renal aorta is easier on the right side	R/W
	Q34 - Aortic prosthesis in the management of a sub-renal aneurysm can lead to ischaemia of the superior mesenteric arteries resulting in mesenteric ischaemia	R/W
	Q35 - Ischaemia of the lumbar arteries can lead to necrosis of the surrounding skin	R/W
	Q36 - Ischaemia of the lumbar arteries can lead to paraplegia	R/W
	Q37 - The superior mesenteric artery passes in front of the right renal vein which explains the risk of varicocele	R/W
	Q38 - Superior mesenteric artery syndrome can result in renal failure	R/W
	Q39 - Compression of the left common iliac vein by the right common iliac artery is possible due to the anatomy of the aortic bifurcation: this is Cockett's syndrome (or May-Thurner syndrome)	R/W
	Q40 - Surgery on the aortic bifurcation may result in retrograde ejaculation due to damage to the superior hypogastric plexus	R/W
	Q41 - The left genital vein may be ligated and then cut during a retroperitoneal approach	R/W

Supplemental material 5 : Anatomical view of carotid artery (Q1-Q5) from David Lee Basset stereoscopic Atlas. Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License.



Supplemental material 6 : Anatomical view of carotid artery (Q6-Q10) Illustration for Traité complet de l’anatomie de l’homme comprenant la médecine opératoire (1831-1854) by Jean-Baptiste Marc Bourgery, Public domain.

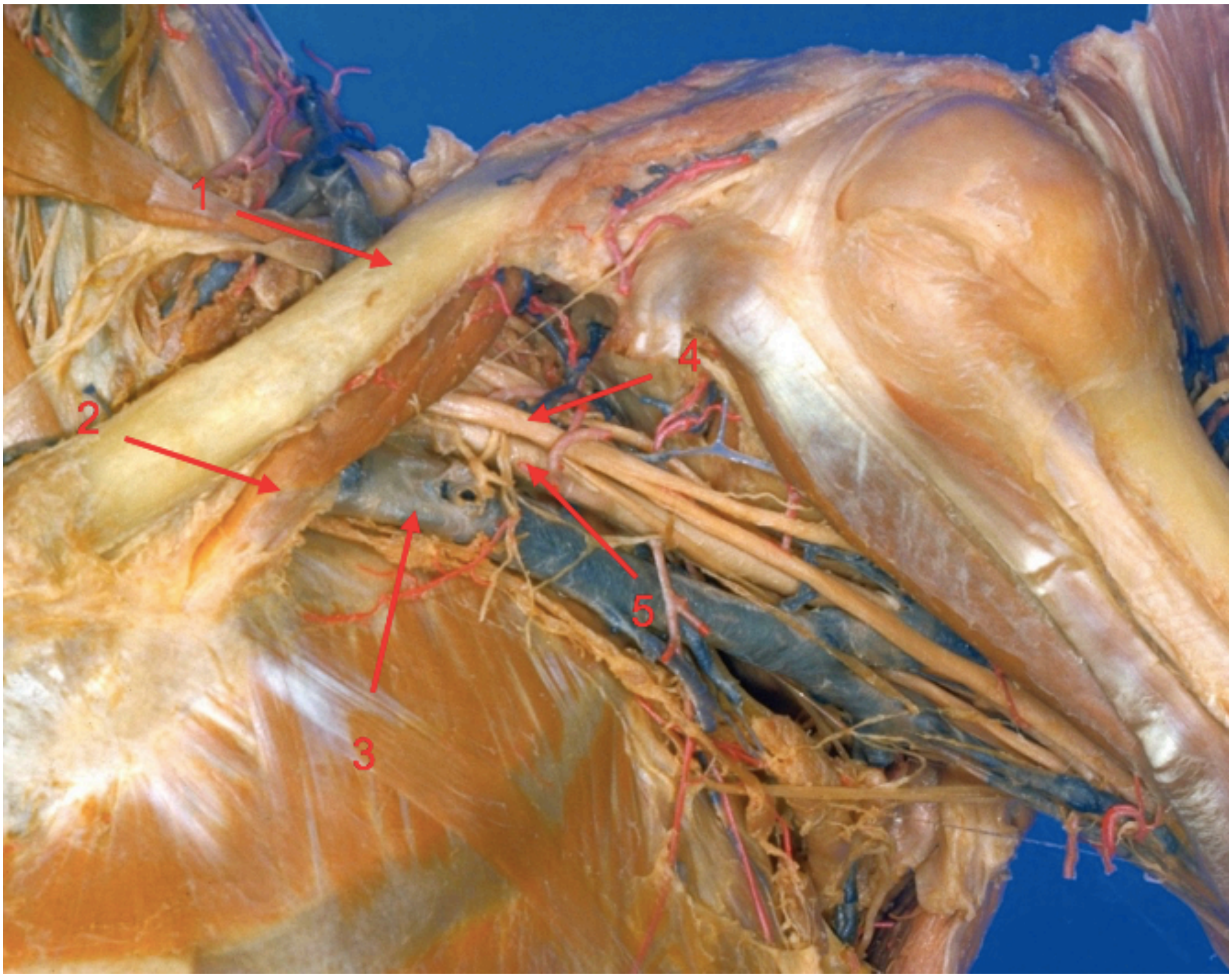


Supplemental material 7 : Anatomical evaluation of abdominal aorta. R/W: right wrong items

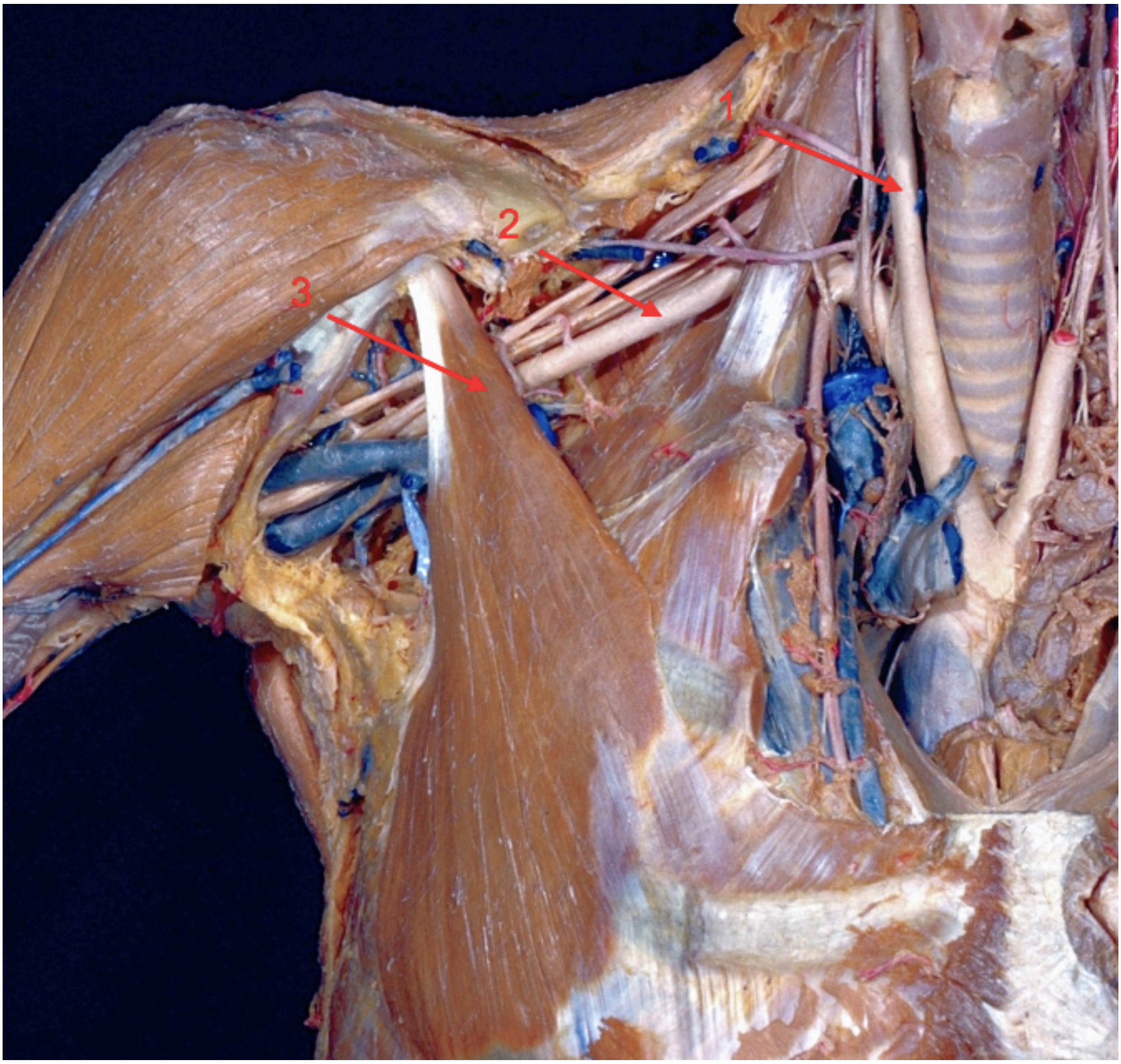
Knowledge evaluated	Questions	Type
Descriptive anatomy	Q1 – Legend 1 = Celiac trunk	R/W
	Q2 – Legend 2 = Inferior vena cava	R/W
	Q3 – Legend 3 = Left Primitive Iliac Artery	R/W
	Q4 – Legend 4 = Left internal iliac artery	R/W
	Q5 – Legend 5 = Right external iliac artery	R/W
	Q6 - Legend 1 = Sub-renal aorta	R/W
	Q7 - Legend 2 = Urethra	R/W
	Q8 - Legend 3 = Iliac muscle	R/W
	Q9 - Legend 4 = Left renal artery	R/W
	Q10 Legend 5 = Inferior mesenteric artery	R/W
	Q11 - The abdominal aorta gives rise to parietal, visceral and urogenital collaterals.	R/W
	Q12 - The subrenal abdominal aorta gives rise to the lumbar arteries.	R/W
	Q13 - Each common iliac artery divides into an internal iliac artery and an external iliac artery.	R/W
	Q14 - The external iliac artery vascularises the pelvic viscera.	R/W
	Q15 - The inferior phrenic arteries are collaterals of the subrenal abdominal aorta.	R/W
Anatomical relationships	Q16 - The aorta enters the abdomen at the level of the T12 vertebra.	R/W
	Q17 - The abdominal aorta is retroperitoneal and follows the right edge of the vertebral bodies.	R/W
	Q18 - The abdominal aorta divides, at the level of the L4 vertebra, into the common iliac arteries.	R/W
	Q19 - The median sacral artery arises at the level of the subrenal abdominal aorta termination.	R/W
	Q20 - The celiac trunk arises at the anterior aspect of the abdominal aorta above the superior mesenteric artery.	R/W
	Q21 - The celiac trunk gives three branches: hepatic artery, splenic artery and left gastric artery.	R/W
	Q22 - The superior mesenteric artery arises at the posterior aspect of the abdominal aorta.	R/W
	Q23 - The inferior mesenteric artery arises from the anterior aspect of the abdominal aorta at the level of the L5 vertebra.	R/W
	Q24 - The arcade of Riolan is an anastomotic network between the superior mesenteric artery and the inferior mesenteric artery.	R/W
	Q25 - The renal arteries arise on the lateral aspect of the abdominal aorta on either side in L1.	R/W
	Q26 - They have a generally horizontal course, slightly oblique downwards and outwards.	R/W
	Q27 - The gonadal arteries arise on the anterolateral aspect of the abdominal aorta above the renal arteries.	R/W
	Q28 - The sub-renal abdominal aorta passes in front of the anterior common vertebral ligament.	R/W

	Q29 - Both the kidneys and the subrenal abdominal aorta are in a retroperitoneal position.	R/W
Reasoning, physiopathology, clinical outcomes	Q30 - Surgery on the subrenal abdominal aorta requires opening the root of the mesentery to mobilise the intraperitoneal contents	R/W
	Q31 - The suprarenal aorta approach is more complex as it requires approaching the duodenopancreatic block via the retroperitoneal route	R/W
	Q32 - Aortic prosthesis in the management of a subrenal aneurysm can lead to phrenic artery ischaemia resulting in ventilatory failure	R/W
	Q33 - The approach to the sub-renal aorta is easier on the right side	R/W
	Q34 - Aortic prosthesis in the management of a sub-renal aneurysm can lead to ischaemia of the superior mesenteric arteries resulting in mesenteric ischaemia	R/W
	Q35 - Ischaemia of the lumbar arteries can lead to necrosis of the surrounding skin	R/W
	Q36 - Ischaemia of the lumbar arteries can lead to paraplegia	R/W
	Q37 - The superior mesenteric artery passes in front of the right renal vein which explains the risk of varicocele	R/W
	Q38 - Superior mesenteric artery syndrome can result in renal failure	R/W
	Q39 - Compression of the left common iliac vein by the right common iliac artery is possible due to the anatomy of the aortic bifurcation: this is Cockett's syndrome (or May-Thurner syndrome)	R/W
	Q40 - Surgery on the aortic bifurcation may result in retrograde ejaculation due to damage to the superior hypogastric plexus	R/W
	Q41 - The left genital vein may be ligated and then cut during a retroperitoneal approach	R/W

Supplemental material 8 : Anatomical view of thoracic brachial outlet with section of the pectoralis minor muscle (Q1-Q5) from David Lee Basset stereoscopic Atlas. Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License.



Supplemental material 9 : Anatomical view of thoracic brachial outlet with section of the clavicle (Q6-Q10) from David Lee Basset stereoscopic Atlas. Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License.



Supplemental material 10 : Anatomical evaluation of thoracic brachial outlet. R/W right wrong items

Knowledge evaluated	Questions	Type
Descriptive anatomy	Q1 - Legend 1 = Clavicle	R/W
	Q2 - Legend 2 = Subclavian muscle	R/W
	Q3 - Legend 3 = Subclavian vein	R/W
	Q4 - Legend 4 = Axillary artery	R/W
	Q5 - Legend 5 = Brachial plexus	R/W
	Q6 - Legend 1 = Right common carotid artery	R/W
	Q7 - Legend 2 = Subclavian artery	R/W
	Q8 - Legend 3 = Pectoralis major muscle	R/W
	Q9 - The clavicle is severed.	R/W
	Q10 - The first rib is not visible on this view.	R/W
	Q11 - The cervical thoracic brachial outlet is defined by 4 successive spaces.	R/W
	Q12 - The scalene pathway is part of the cervical thoracic brachial pathway.	R/W
	Q13 - The costo-clavicular canal is part of the thoracic brachial outlet.	R/W
	Q14 - The supra pectoral tunnel is part of the thoracic brachial parade.	R/W
	Q15 - The humeral neck is part of the thoracic brachial outlet.	R/W
Anatomical relationships	Q16 - The costoclavicular canal is located between the distal part of the clavicle and the first rib.	R/W
	Q17 - The anterior and middle scalene muscles are elements of the costoclavicular canal.	R/W
	Q18 - The subclavian vein is medial to the subclavian artery.	R/W
	Q19 - The subclavian artery lies outside the C8T1 nerve roots.	R/W
	Q20 - The subclavian muscle passes in front of the lower surface of the clavicle.	R/W
Reasoning, physiopathology, clinical outcomes	Q21 - Thoracic brachial outlet syndrome is a chronic pain syndrome.	R/W
	Q22 - The thoracic outlet syndrome has a dynamic component.	R/W
	Q23 - The thoracic brachial outlet syndrome is caused by compression of the vascular and nervous structures.	R/W
	Q24 - The costo clavicular canal is part of the thoracic brachial outlet.	R/W
	Q25 - Resection of the clavicle is one of the treatments for thoracic brachial outlet syndrome.	R/W
	Q26 - Resection of the first rib is the gold standard surgical treatment for thoracic brachial outlet syndrome.	R/W
	Q27 - The section of the pectoralis minor muscle can be associated with the resection of the first rib.	R/W
	Q28 The Roos axillary approach allows for resection of the first rib.	R/W
	Q29 The Roos axillary approach passes in front of the pectoralis minor muscle.	R/W
	Q30 None of the four previous proposals is correct.	R/W

DEFAY Arthur

Est-il utile de créer un programme d'enseignement d'anatomie 3D pour l'internat de chirurgie ?

RÉSUMÉ

Introduction : La technologie de réalité virtuelle (RV) permet la création de vidéo éducatives qui incorporent des séquences stéréoscopiques tridimensionnelles (3D). Combinée à la dissection anatomique en 3D, toute procédure chirurgicale ou pathologie peut être représentée virtuellement pour compléter l'apprentissage anatomique et la planification préopératoire. **Méthodes :** Une étude prospective cas-témoins a été réalisée pour évaluer l'impact de l'enseignement anatomique par réalité virtuelle. Les participants ont été répartis de manière randomisé en deux groupes : (1) Enseignement anatomique stéréoscopique à l'aide d'une vidéo pédagogique et (2) enseignement classique à l'aide de livres anatomiques et chirurgicaux, concernant le syndrome du défilé thoraco brachial. Au préalable, les internes ont passé un test anatomique commun sur l'aorte abdominale et l'artère carotide pour évaluer leurs connaissances de base en anatomie vasculaire. Les performances avant et après le test ont été analysées avec des tests t indépendants évaluant les connaissances anatomiques de base, les relations anatomiques et le raisonnement clinique. En parallèle, une enquête nationale auprès des internes en chirurgie vasculaire a été réalisée à l'aide d'un formulaire d'évaluation sur une échelle de Likert en 5 points concernant les besoins pédagogiques du programme d'anatomie en chirurgie vasculaire. **Résultats :** Sur les 20 étudiants inclus, il n'y avait pas de différence significative sur les résultats portant sur l'aorte abdominale (moyenne 78,78% vs 76,34%) et l'artère carotide (moyenne 78,57% vs 74,76%). Après visualisation de la vidéo pédagogique ou l'apprentissage sur livres anatomiques, il y avait une différence statistique ($p<0,05$) entre le groupe vidéo (n= 10, 90%) et le groupe d'enseignement classique. Tous les internes ayant visualisé la vidéo ont estimé que cette méthode leur semblait indispensable à leur formation anatomique (100%). Parmi les 54 internes en chirurgie vasculaire ayant répondu à l'enquête nationale, la plupart ont estimé qu'il y avait un manque de ressources pédagogiques en anatomie chirurgicale (69,6%). Tous ont convenu qu'un programme d'enseignement de l'anatomie chirurgicale certifié par des chirurgiens et des anatomistes était nécessaire (100%). **Conclusions :** La vidéo d'enseignement avec stéréoscopie 3D semble être un outil d'enseignement utile et complémentaire. Dans une étude future, il sera nécessaire d'évaluer l'apport de cet enseignement à long terme et la possibilité de l'intégrer dans la formation des chirurgiens vasculaires.

Mots-clés : Pédagogie ; Chirurgie vasculaire ; Anatomie ; 3D ; stéréoscopie

Is it useful to create 3D clinical-based anatomical teaching programs in surgical residency?

ABSTRACT

Introduction. Current virtual reality (VR) technology allows for the creation of instructional video formats that incorporate three-dimensional (3D) stereoscopic footage. Combined with 3D anatomic dissection, any surgical procedure or pathology can be represented virtually to supplement anatomical learning and surgical preoperative planning. **Methods.** A prospective case-control study was completed to evaluate the impact of virtual reality anatomical teaching. After a prerequisite anatomical knowledge assessment, participants were randomized in two-groups: stereoscopic anatomical teaching program versus classic teaching of thoracic brachial outlet syndrome. Then, students completed a written anatomical test to assess their basic knowledge in vascular anatomy. Pre- and post-test performances were analyzed with independent t-tests for total score assessing basic anatomical knowledge, anatomical relationships and clinical inference. Afterwards a French national survey of vascular surgery residents was carried out using a 5-point Likert scale evaluation form. It evaluated the pedagogical needs in the vascular surgical anatomy curriculum from the students point-of-view. **Results.** Before performing the teaching, the 20 students included were homogenous in term of total exam note in abdominal aorta (mean 78,78% vs 76,34%) and carotid artery evaluations (mean 78,57% vs 74,76%). After the course, there were statistical difference ($p<0,05$) between the stereoscopic 3D video group (n= 10, 90%) and classical teaching group concerning the total exam note, descriptive anatomy, anatomical relationships and clinical inference skills. All the students thought this method (accessible on mobile, computer and virtual reality headsets) seemed indispensable to their anatomical training course (100%). Among 56 residents, most felt that there is a lack of educational resources in surgical anatomy for residents entering vascular surgery residency (69,6%). All agreed that a surgical anatomy teaching program certified by clinicians and anatomists is needed (100%). **Conclusions.** The teaching video with 3D stereoscopy seems to be a useful and complementary teaching tool useful that is approved by the residents themselves. In a future study, it will be necessary to evaluate the contribution of this teaching in the long term and the possibility of integrating it into the vascular surgeon curriculum worldwide.

Keywords : Pedagogy; Vascular Surgery; Anatomy; 3D; stereoscopy

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