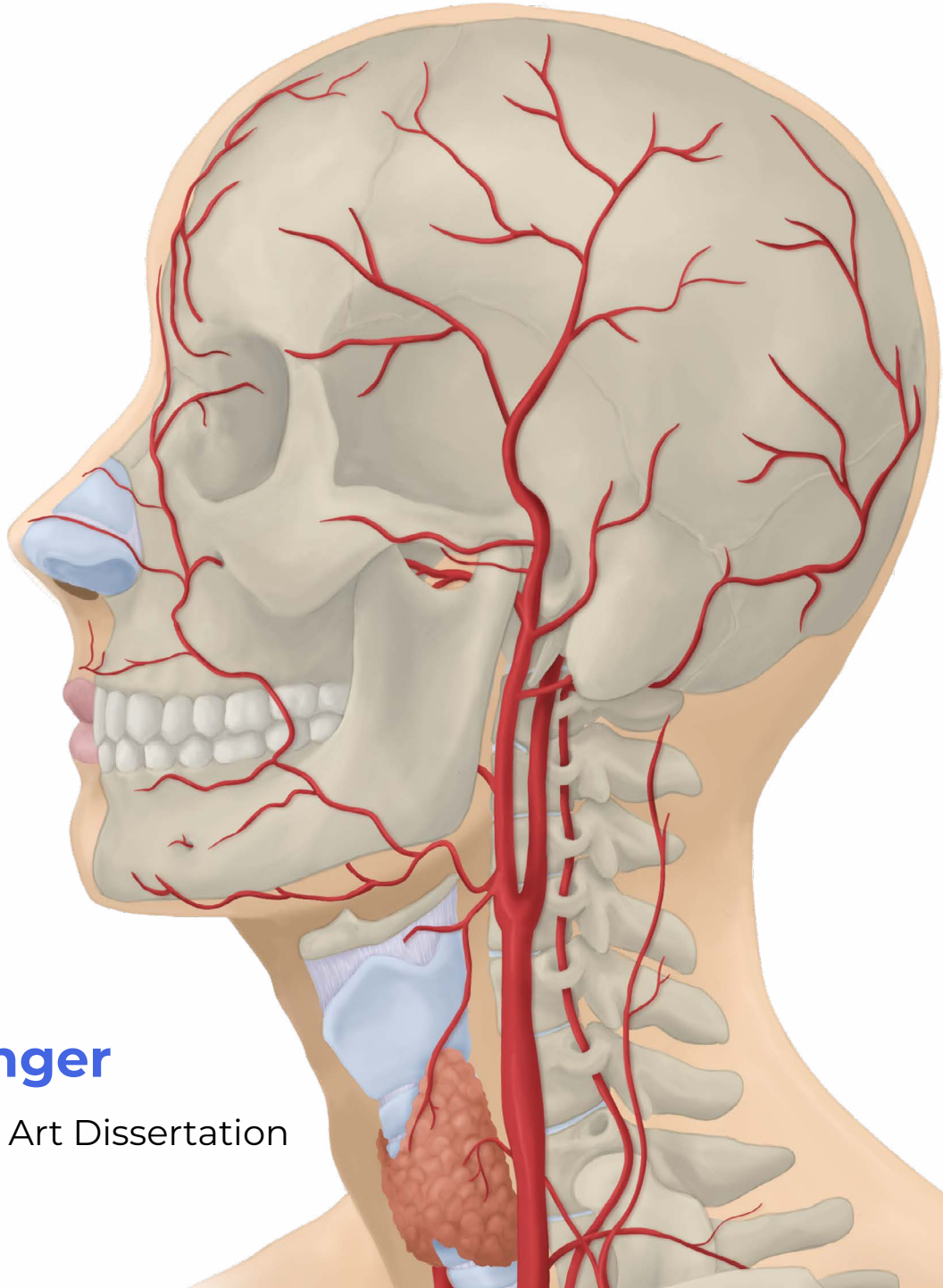
HEAD & NECK ANATOMY

Creating an Illustrative Resource to aid with Otorhinolaryngology Anatomy Revision in Education



Kate Breininger

2025 MSc Medical Art Dissertation

DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university, or institute of l earning. The research presented in this thesis is my own, including any mistakes, unless otherwise stated.

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Project Supervised by Dr Caroline Erolin and Eve Laws

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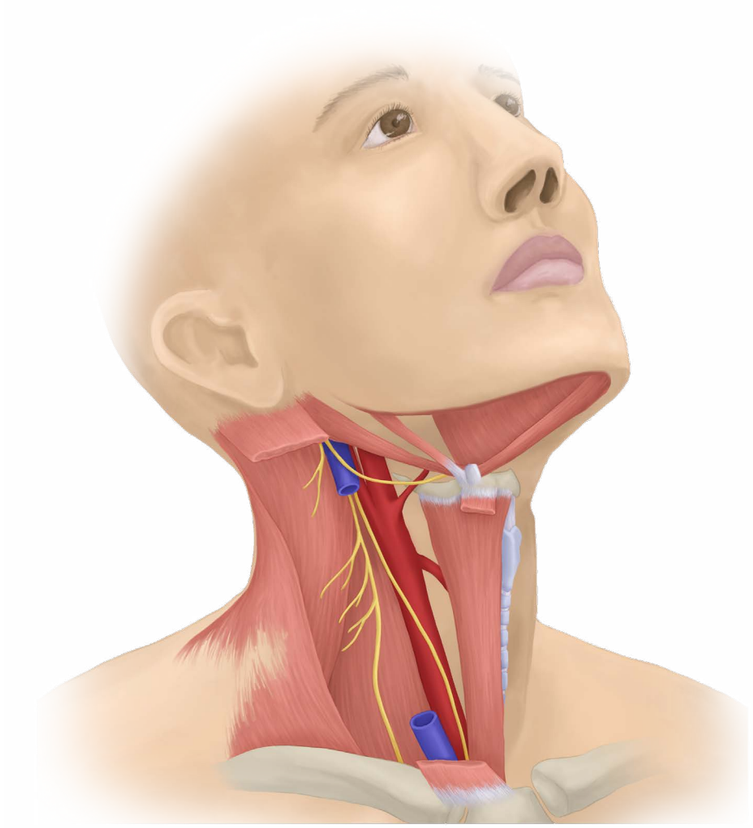


INTRODUCTION

The head and neck are considered some of the most complex and difficult regions of the body to learn, and it is important that both medical students and professionals properly understand them. Medical technology is constantly evolving, and our understanding of the human body along with it. Medical illustrations play a prominent role in communicating this knowledge, especially in education, so keeping these resources up to date and easily accessible helps to ensure better comprehension of the subject matter.

Medical Illustrations can be produced using a variety of media and styles, but they can vary in degrees of detail and realism, making it difficult to establish a consistent understanding of the different layers of anatomy and how structures relate to each other.

The Surgical Skills Centre at the Dundee Institute of Healthcare Simulation provides procedure-based skills courses for medical personnel at a variety of experience levels. The current resources used by the Surgical Skills Centre come from a variety of sources and have different resolutions, styles, and levels of detail. The aim of this project is to establish a consistent, detailed, accurate resource in the form of an interactive online module containing a selection of head and neck anatomy structure illustrations for the otorhinolaryngology (ENT) courses at the Surgical Skills Centre. For this project, six two-dimensional (2D) illustrations were created to be used in place of the current ones. By making a consistent series of interactive labeled illustrations featuring different structures such as the muscles, circulatory system, and neck compartments, as well as more technical subjects like tracheostomy placement and visualization of the parapharyngeal space. Participants of the courses that utilize this resource may have a more beneficial learning experience in comparison to using the inconsistent and/or lower quality images that these are replacing. The illustrations for this project were developed in collaboration with the ENT department at NHS Tayside, and the University of Dundee School of Medicine Technology and Innovation in Learning Team (TILT). This resource primarily aims to help refresh the knowledge of professionals in continuing education ENT courses, but it can also be useful for medical education of undergraduate and postgraduate students.

LITERATURE REVIEW

ENT EDUCATION

The head and neck regions are considered by both students and educators as some of the most difficult regions to learn. There are many different structures and systems contained in the relatively small space, and teaching about them can be particularly challenging. Rehman et al. (2022) raise concerns about the quality and quantity of head and neck anatomy education that medical students receive, and how that impacts their eventual entry into the professional field. Medical students were surveyed to evaluate how much head and neck anatomy teaching they received as part of their curriculum, teaching methods, what they thought were the hardest anatomical topics to learn, and their opinions on if they felt they received an adequate amount of education in the head and neck region. 72% of students disagreed with getting an adequate amount of teaching, and decreased confidence amongst new doctors entering the specialty fields involving the head and neck. The lack of an in-depth understanding and knowledge in these areas can decrease the quality of care these people can provide in the professional setting or even turn students away from careers in those specialties altogether.

These issues are a prominent cause for concern, especially when it comes to the otorhinolaryngology (ENT) field. With an inadequate curriculum of general head and neck anatomy teaching, specific subjects in these specialized fields will be even more underrepresented. Khan and Saeed (2012) found that the current practice for ENT clinical training varied between the 30 medical schools represented. Ten of the medical schools did not have formal ENT sections in their curriculums, and 47% of students reported that they did not have access to mandatory ENT placement for their training and those who did had an average placement of eight days. Otorhinolaryngology is the third largest specialty in the hospital setting, but the lack of exposure in education poses a difficult position for medical students and new doctors. The reason for the limited ENT education in undergraduates is mainly due to the time available in the curriculum and different delivery methods of teaching (Yip et al., 2020).

Further training and education can occur in postgraduate and continuing medical education courses. As ENT is very prominent in the medical field, it is important that the unmet educational needs are addressed here. A survey by Sharma et al. (2006) discusses that a better option is to postpone ENT teaching until the postgraduate level where it would be more clinically relevant as it is more specialized. The accessibility of resources and courses for further education has the potential to improve the quality of training for those planning to go into this field. Easto and Reddy (2016) note that many postgraduate trainees would have liked the opportunity to get further training “specifically by way of relevant and easily accessible courses.”

While the undergraduate and postgraduate portion of ENT education could benefit from some improvements, it is also very important that practicing medical professionals stay refreshed and up to date with their knowledge. Continuing medical education (CME) is a necessary part of maintaining quality of care and can even be used to improve and reinforce the skills of those who may have had sub-par undergraduate training.

The resources available for CME are different from those used for students, and there is more flexibility in how they are utilized. There is no formal structure for how CME for ENTs is carried out, and many have stated they preferred that, as they should have the ability to determine their own educational needs as professionals. The best method as to how this continued education is delivered is under debate, as many ENTs use the traditional methods like journals and conferences, but more modern resources such as e-learning, simulations, and podcasts are on the rise as well (Victoria et al., 2016). Evidence suggests that using multiple delivery methods for teaching results in better knowledge gain compared to only using a single method (Gupta et al., 2019).

Accessibility of continuing medical education resources for ENTs used to be limited, with teaching primarily delivered in the format of conferences, seminars, demonstrations, or journals. A survey of Canadian ENTs conducted by Hamilton et al. in 2003 examined the methods they practice CME, and 76% of respondents expressed interest in online programs, and that they preferred self-study modules as a method of delivery. Online modules are becoming more commonplace in the modern technological age, which can allow for a larger audience for these CME resources. These are generally provided by professional bodies, and offer things like webinars, e-learning modules, and virtual conferences. There are e-learning modules (paid and free) provided by many different organizations and are built around interactive web-based learning, featuring instructional videos, photographic and illustrative imagery, and detailed summaries and descriptions (ENT UK, 2020). As technology advances, so does the potential to enhance the continuing medical education learning experience.

EDUCATIONAL USES OF MEDICAL ILLUSTRATIONS

Medical illustrations have revolutionized the way medical education is taught, and its educational potential has only increased as technology has developed. Concerns have been raised about the quality of medical training, and it’s been noted that medical illustration has become an increasingly important role in improving it. The development of digital media can potentially impact the effectiveness

of medical education in a major way. In the modern age of medical education, interactive computer-aided learning, digital communication, and virtual reality offer many applications of accessible learning materials. Afzal Ansary and Meguid El Nahas (2000) note that the availability of these resources is especially important for the development of CME courses, which can allow 24-hour access, along with interactive self-instruction and the ability to distribute to a wider audience in comparison to more traditional teaching methods.

Interactive media has an advantage over books for teaching, as being able to interact with it makes it more stimulating and can enhance the learning process. Mayer's multimedia theory of learning asserts that people learn best from a combination of words and pictures, and that it is more effective to present information in segments and allow the user to control the speed of which they view it (Digital Learning Institute, 2023). This is helpful when applied to presenting medical illustrations because it can allow the user to take their time to understand what is being visualized. For example, an anatomical illustration can be presented as a whole but allows the user to go into deeper detail on the different structures depicted individually, which would be more effective than just showing all the information at once. Structuring the delivery of information in this format has demonstrated that learning with the use of interactive visualizations can be significantly improved, in comparison to learning with only static visualizations (Bodemer et al., 2004).

When it comes to illustrating visual materials used in education, the level of realism and detail needs to be taken into account. As medical illustrations have a wide range of applications and audiences, the ones made for educational use of students and professionals tend to be on the more detailed side. The purpose of these materials must also be taken into account when a medical artist is determining the level of detail and complexity when developing medical illustrations. Strong and Erolin (2013) found that 67% of professionals prefer high detail illustrations for complex subjects, as opposed to medium and lower detail depictions. Illustrations used for the education of students and medical professionals benefit from more complexity as the audience already has some knowledge of the subject beforehand.

OPINIONS OF PROFESSIONALS

The contributions of medical illustration to the ENT field are particularly prominent due to their ability to depict areas of anatomy that are generally difficult to distinguish and visualize. A study by Kaya et al. (2021) using three different instructional methods for dorsum preservation rhinoplasty compared the effectiveness of using written only descriptions of the surgery steps, step-by-step photos of the surgery, and medical illustrations. The participants were asked "Do illustrations of the surgical procedures express the subject better than photography and written expression?" by

which 78% of the participants agreed. Digital and multimedia teaching is currently considered more effective than traditional teaching, and visual-based surgical skills training can improve surgical skills combined with verbal feedback in comparison to verbal feedback alone. The transfer of knowledge is important when developing visual resources. The participants in the study generally stated that using exclusively photographs was inadequate at portraying all of the information, and that using the illustrations alongside the photos was more effective and memorable. With the usage of modern technology, being able to visualize and communicate the complexities of these structures, medical illustrations can help to improve the understanding and comprehension of anatomical structures and surgical procedures in the ENT specialty.

SUMMARY

Current curriculum has been shown to lack extensive learning opportunities in the ENT specialization, leading to many students – both undergraduate and postgraduate – feeling like they didn't have a very in-depth understanding of the subject. The accessibility of proper ENT training opportunities could benefit from some improvements, as the ENT field is one of the largest specialties in the medical industry. Many ENT students and professionals look favorably upon more accessible learning resources and training opportunities, specifically in continuing medical education. As it is important for professionals to keep up to date with their knowledge, online CME courses and resources have started to become more commonplace. Interactive resources have demonstrated improved information comprehension in comparison to other methods. Medical illustrations have a prominent role in medical education, and modern technology allows for the integration of interactivity to improve learning outcomes.

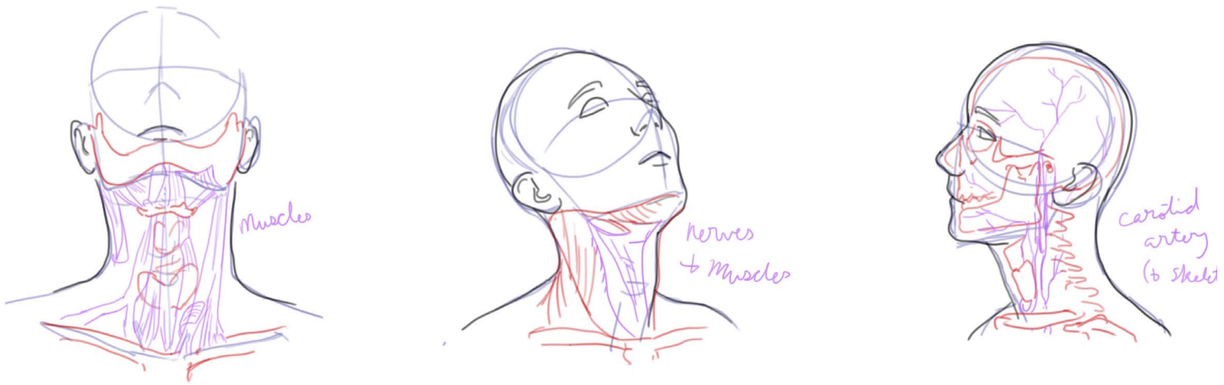


Figure 1: *Early sketch work for the orientations and layouts of the series of illustrations*

METHODOLOGY

This project was based on creating a resource of refreshed and updated illustrations to replace the ones currently used in the ENT courses by the Surgical Skills Centre at the Dundee Institute of Healthcare Simulation. The original illustrations that were provided during the project brief came from various different online sources and creators, and they varied in different levels of detail, art style, and image quality. During the brief, it was decided that it would be best to make a series of illustrations that were consistent in style and detail for usage in the continuing medical education courses being taught. An interactive version of the illustrations in the format of an online module was also produced for learning and revision purposes. As different stages of the project were developed, feedback for anatomical accuracy and compliance regarding the original request was sought from project supervisors at regular intervals to ensure quality and consistency. Creation of this resource primarily utilized Adobe Photoshop, Adobe Illustrator, and Lumi Education software.

Creating the Illustrations

After the project brief, the TILT team provided six different illustrations that needed to have updated versions created:

- Anterior neck muscles
- Veins and arteries around the trachea and thyroid
- Anatomical location and placement of a tracheostomy tube
- Subdivisions of the neck compartments
- Anatomy of the external carotid artery
- Visualization of the parapharyngeal space

(See Figures 4, 11, 15, 22, 27, 28, and 35)

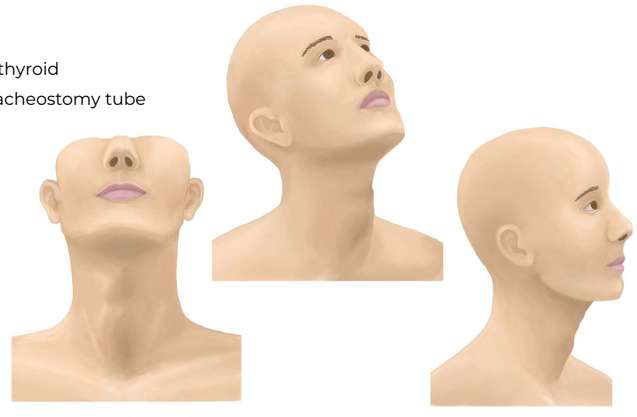


Figure 2: *Three head angles illustrated; front-facing (left), three-quarters (middle), profile (right)*

DEVELOPMENT OF NEW ILLUSTRATIONS

The illustration work from sketch to final was created in Adobe Photoshop (2025) on a Microsoft Surface Pro. Some initial sketch work was done using similar angles and orientations of the proposed illustrations. Three different head angles were initially illustrated to provide the viewer with a reference to the overlaid anatomical structures: a front-facing angle, three-quarters angle, and profile angle (Figure 1). As each angle only focuses on specific regions and structures, not all of the same structures are featured across the series. Alongside the original images provided by TILT, a combination of online sources and textbooks were used as references (AnatomyZone 2025, Clinicalanatomy.ca 2025, Rohen et al 2007, Rohen et al 2016) for creating the illustrations.

Three different head illustrations (Figure 2) that would serve as the bases for the anatomy structures were developed using original photographic references of the head taken by the author. These were used as a starting point for identifying surface anatomy and shadows. Once the general anatomy was identified, the different structures were blocked out using linework and solid colors. The work on the main portions of the illustrations progressed in phases, with shapes and positioning checked and updated for anatomical accuracy after each one. The illustrations were all worked on at the same time to ensure consistency across the series. The general phases consisted of rough linework > solid shapes > texture and shading > fine detail > linework (Figure 3). These progressive stages of work were organized on different Photoshop layers and groups to allow for individual adjustments. Once the texture and shading were finished, each illustration got more individual attention for working on the fine detail.

The individual illustrations were created on 3,300 by 3,300-pixel canvas in RGB color. The materials used were the default brushes that come with Photoshop – the Soft and Hard Round Pressure Size brushes – which work well with the Microsoft Surface Pro touch screen and Surface Pen. Texture creation and blending was done using a mix of the soft round pressure brush and Kyle's Impressionist Blender. Shading was enhanced using the Dodge and Burn tools to create contrast in the highlights and shadows. The same color palette was used for all six illustrations to ensure consistency.

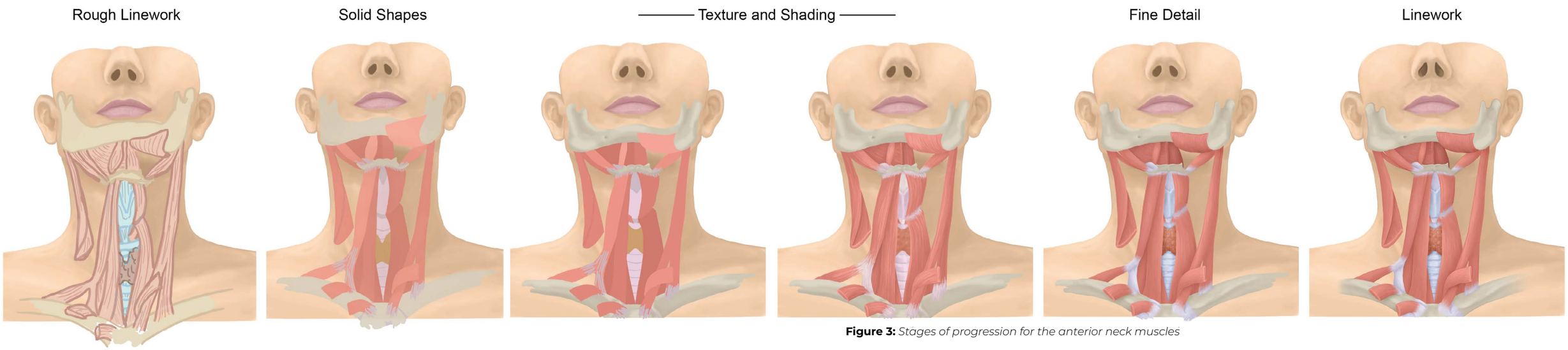


Figure 3: *Stages of progression for the anterior neck muscles*

ANTERIOR NECK MUSCLES DEVELOPMENT

The image of the anterior neck muscles originally provided somewhat shaped the style of the final series of images, particularly related to the way the anatomy was overlaid on a photograph of a person (Figure 4). This inspired the creation of the three head angle bases which are used in all of the illustrations.

The trachea and skeletal structures were originally created as a framework for the placement of the muscles that needed to be depicted. Using different layers in Photoshop, each of the muscles were illustrated separately with varying shades to create a layered effect emulating the superficial and deep layers of the anatomy. One of the initial rounds of feedback received from the TILT team noted that the neck was a bit too long and caused some confusion for the placement of some of the structures (thyroid, hyoid bone, cartilage). This was amended by shortening the distance between the head and the shoulders and adjusting the structures accordingly. (Figure 3)

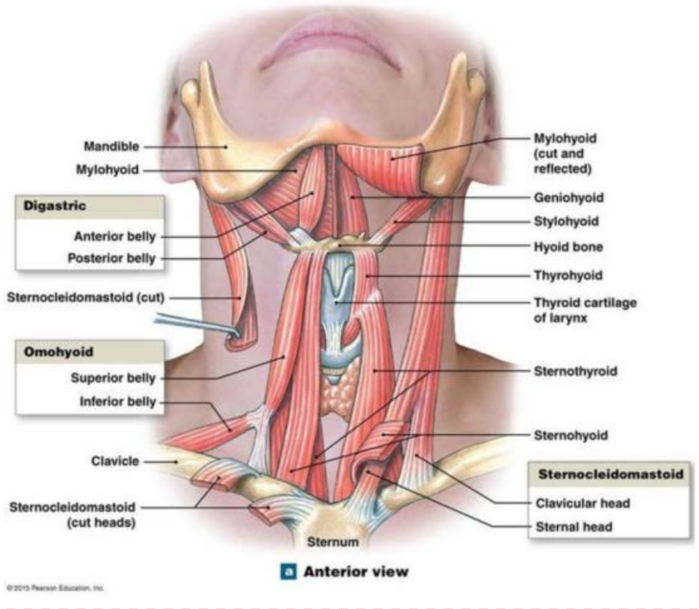


Figure 4: *Image of the anterior neck muscles provided by the TILT team. Copyright © by Pearson Education, Inc.*

Shading and texturing was started on the layers containing the trachea and skeletal structures first. For this step, another layer was created right above the shape layers containing the specific structures, with the magic wand tool used to select the shape of the structure, which ensured no brushstrokes went outside the specified area. The next structures worked on were the deep muscles, then the muscles overlaid on them and so on, with tendons being the final. Throughout this process, each of the six illustrations were worked on in the same development stages, with no progression to the next stage until all of them were on the same level. Aside from the neck length, the only other notable feedback suggestion was to change the tracheal cartilage color from dull purple to a light grey-blue and remove one tracheal ring. As the trachea was visualized across the series of illustrations, this color change was applied to the other ones as well.

Finer detail and shading occurred similarly to the last step, with more individual focus on each specific layer. The tendons and muscles received the most attention in this stage as they would be the focus of the illustration. Portions of the clavicles and the mandible were faded out using the soft round pressure eraser to make them appear more connected to the base head illustration. On a final top layer, subtle linework was added to allow for better differentiation between the structures and contrast against the skin layer. This was exported as a PNG, which was then opened separately, and the soft round pressure eraser was used to fade out the edges of the head and shoulder areas to make the overall image appear cleaner with less harsh edges (Figure 5).

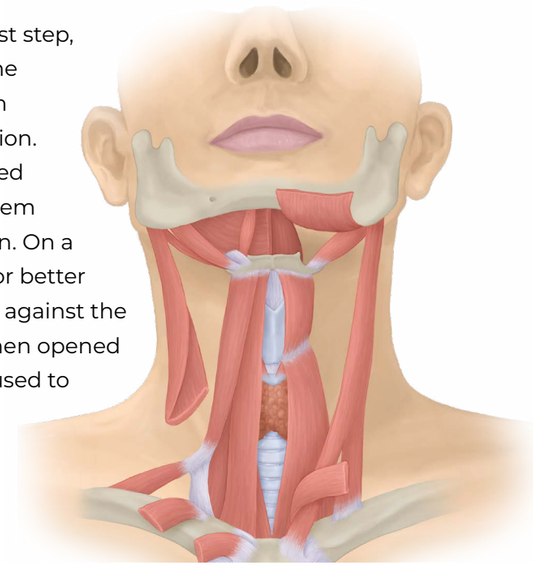


Figure 5: *Final stage of the illustration with faded edges*

Final Detailing

In Adobe Illustrator, Figure 5 was placed centered on an artboard. The labels from figure 4 were transferred to the Illustrator document in Arial 40pt (regular and bold) and assigned accordingly using the pen tool to create a line with a 3pt stroke between them. This was exported as a PNG at 300ppi.

Later feedback yielded a request to increase the width of the Sternocleidomastoid muscle by 50% as it appeared a bit too thin in the earlier version. This was done using a copy of the muscle on a different layer and resizing, adjusting, and blending it to achieve the outcome in Figure 6. Labels in Illustrator were subsequently adjusted accordingly (Figure 7).

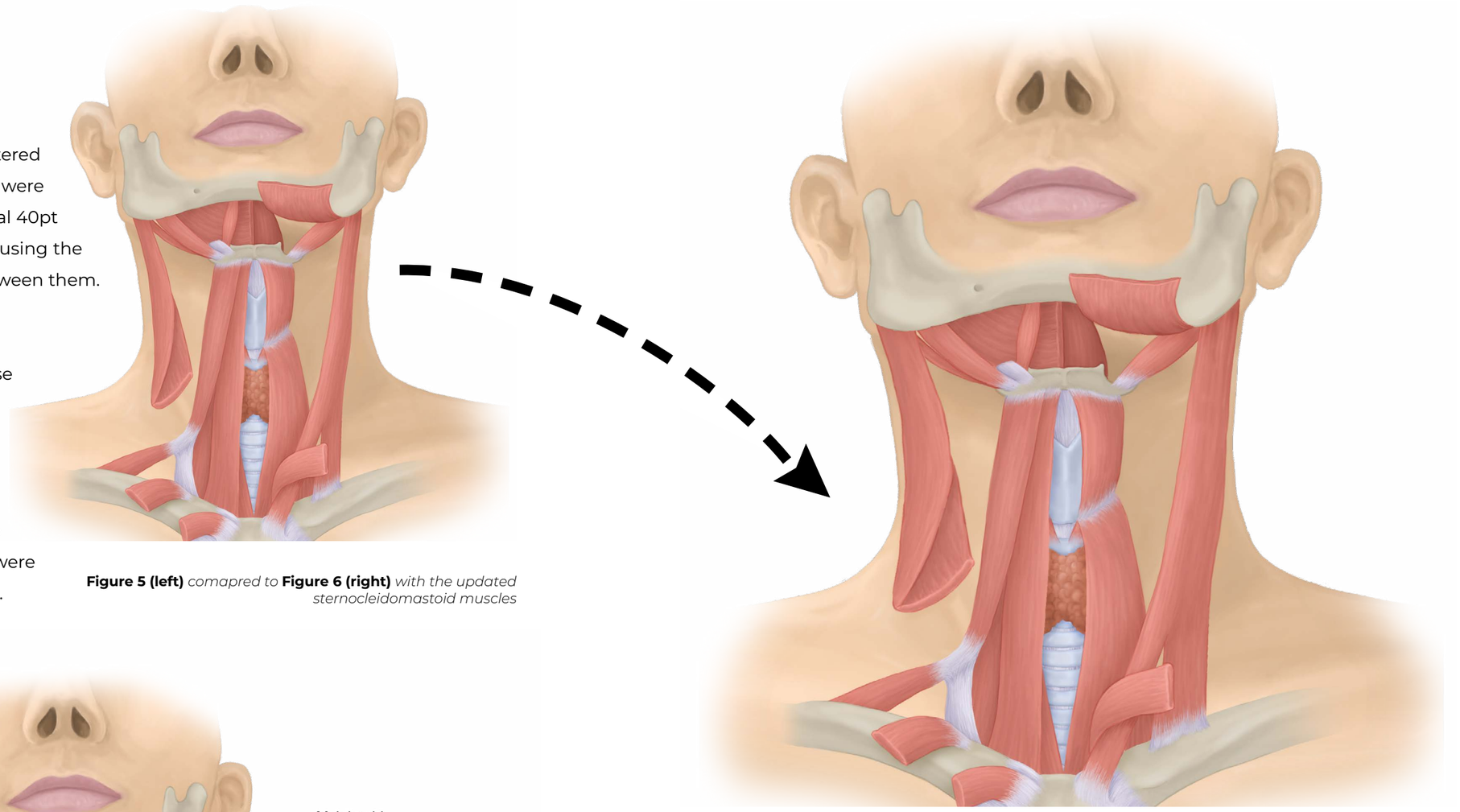


Figure 5 (left) *comapred to* **Figure 6 (right)** *with the updated sternocleidomastoid muscles*

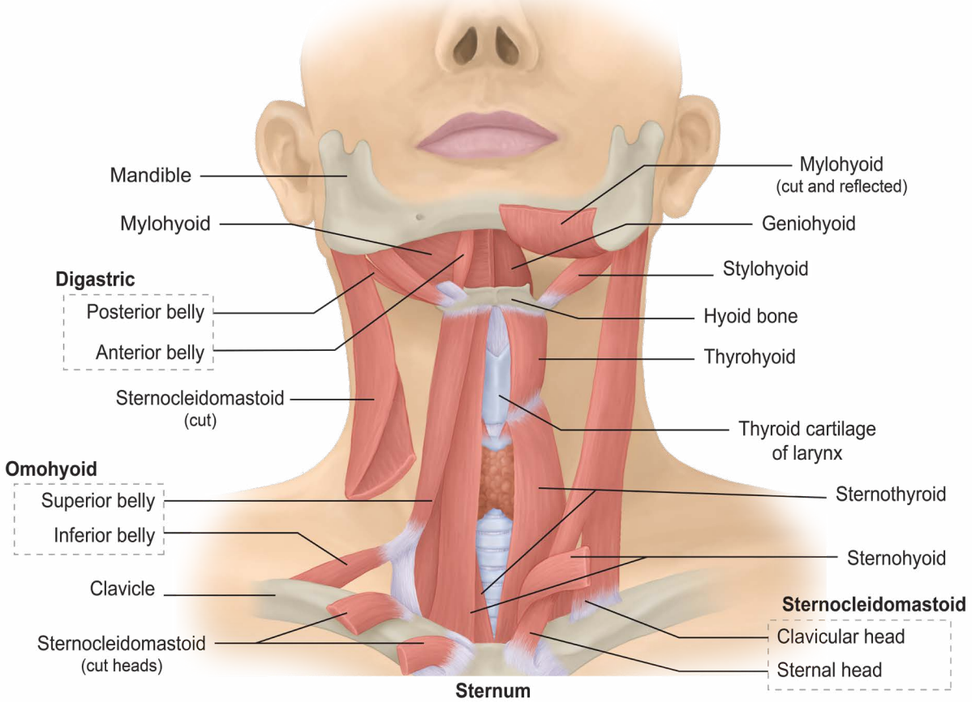


Figure 7: *Final Illustration labelled in Illustrator (For larger image, see Results section)*

Separate isolated versions with labels specifically pointing to the sternocleidomastoid, omohyoid, sternohyoid, sternothyroid, and digastric muscles identified to be used in the interactive resource.

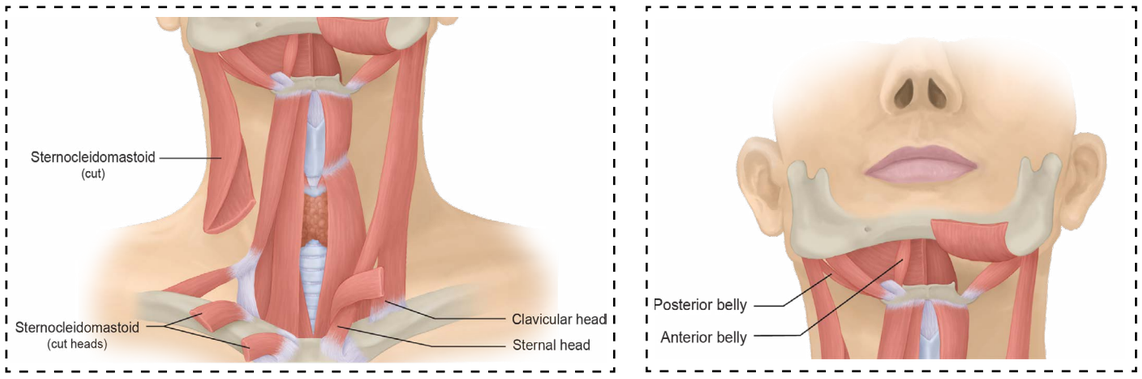


Figure 8 & 9: *Examples of the isolated labeled versions exported for the interactive resource (sternocleidomastoid & digastric)*

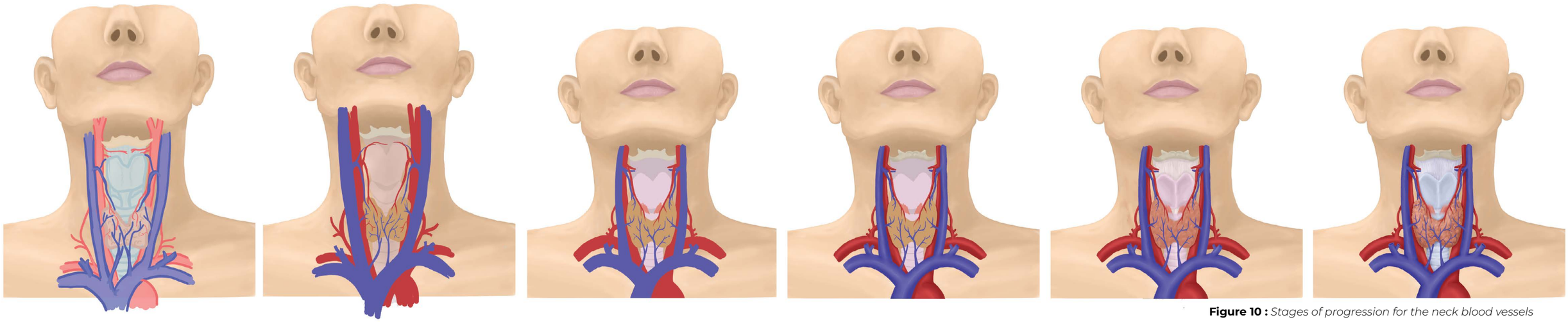


Figure 10 : *Stages of progression for the neck blood vessels*

VEINS AND ARTERIES DEVELOPMENT

The original veins and arteries illustration was an older low-resolution image by Frank Netter from a textbook (Figure 11). Because of the image quality, it was difficult to identify many of the smaller, finer details. It also had nothing to give the viewer a sense of general positioning as it was just a visualization of the area, making it difficult to ascertain its general location on the body.

In the early stages of illustrating this, feedback received stated that the neck was too long, and it was creating a bit of confusion in the relative placement of the thyroid, tracheal cartilage, and minor blood vessels. This was amended and permission granted to continue in development. Since this anatomy was going to be overlaid on the same head as the anterior muscles, the thyroid, trachea, and hyoid bone shapes are the same assets used in that illustration and are placed in the same location to ensure accuracy. The nerves and pyramidal lobe of the thyroid are omitted in the new illustration, as the focus of the subject is on the thyroid and blood supply. (Figure 10)

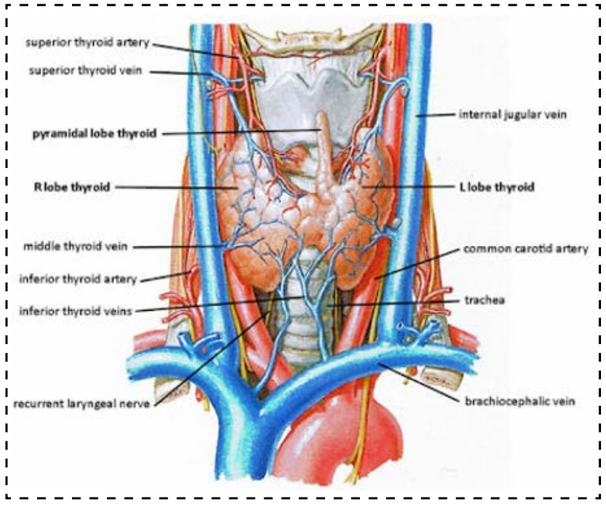


Figure 11 (left): *Image of the trachea and thyroid blood vessels provided by the TILT team. Copyright © by Elsevier.*

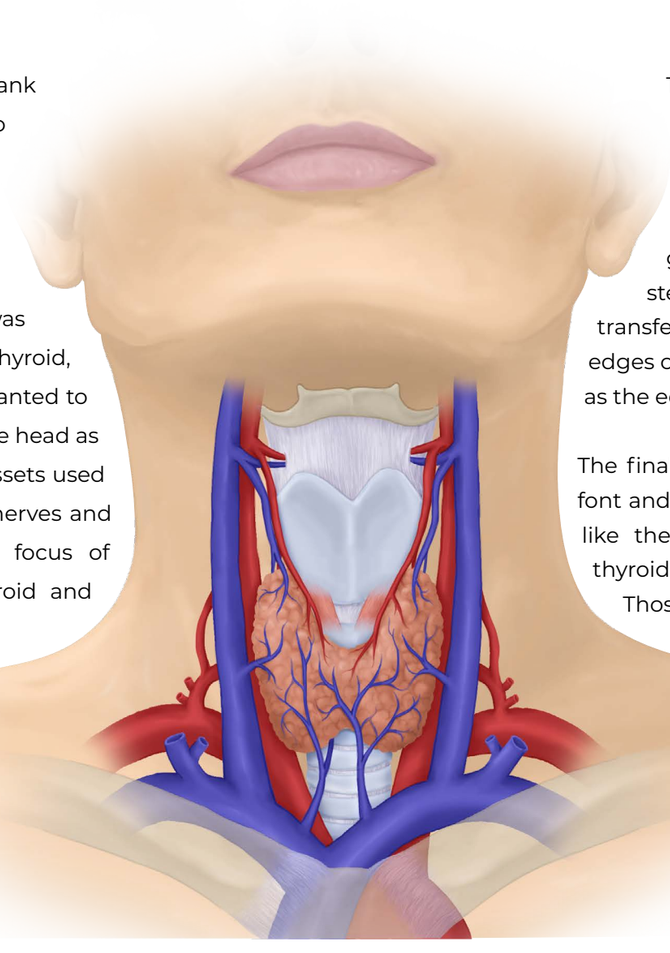


Figure 12 (above): *Final Illustration with faded edges*

The order of layering on this illustration started with the trachea and hyoid bone, to major arteries, major veins, thyroid, minor arteries, and then minor veins. Shading and texturing were performed in a similar manner to the anterior neck muscles. In regard to feedback at these stages, the color of the trachea was changed from dull purple to grey-blue. A later discussion yielded the addition of a partially transparent sternum and clavicle over the veins and arteries, which just required a transfer of the asset from the other illustration and some minor editing. The edges of the vessels were faded out using the soft round pressure eraser as well as the edges of the head and shoulder areas following. (Figure 12)

The final PNG illustration was placed in Illustrator and labeled with Arial 40pt font and 3pt strokes. The software was also used to outline individual structures like the superior thyroid veins and arteries, middle thyroid veins, inferior thyroid veins, and trachea with a 2pt white line on un-labeled versions. Those were also exported as PNGs which will be used in the interactive resource. (Figure 13)

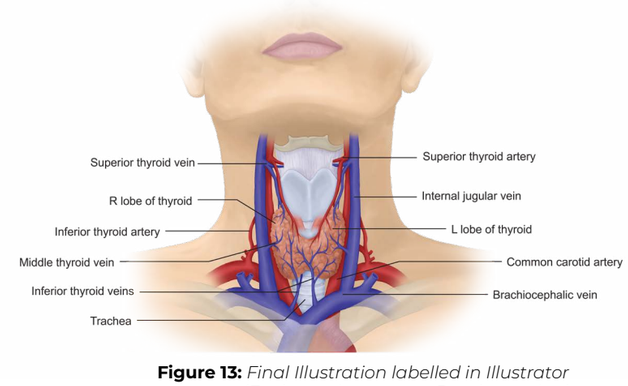


Figure 13: *Final Illustration labelled in Illustrator (For larger image, see Results section)*

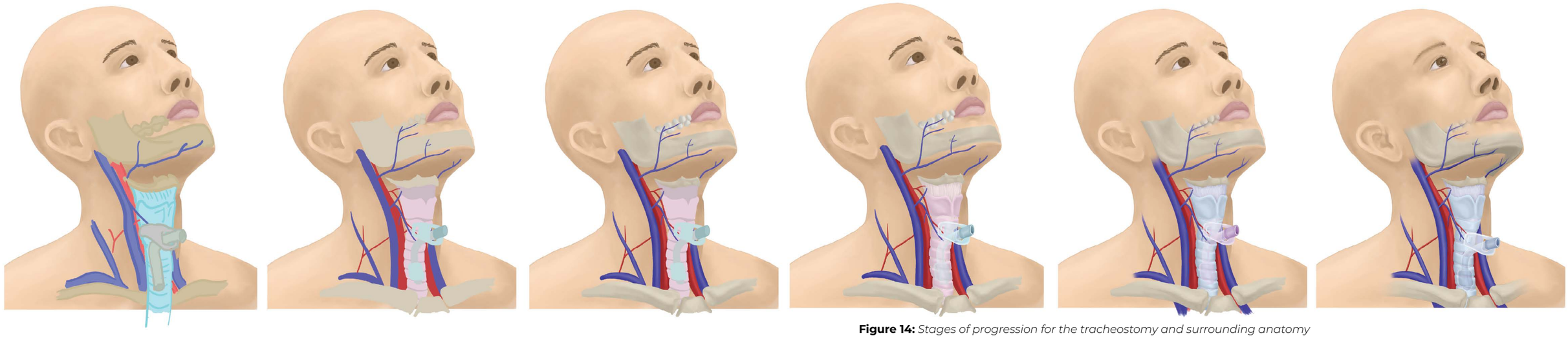


Figure 14: *Stages of progression for the tracheostomy and surrounding anatomy*

TRACHEOSTOMY DEVELOPMENT

The tracheostomy illustration is notable because it is the only one in the series that features more than just anatomical structures (Figure 15). While the person in the illustration from TILT is positioned horizontally, the pose is still quite similar to the neck compartment illustration (figure 22), which is more of a three-quarter angle with the head tilted upward. The initial illustration was made with the person oriented upright and a plan to turn it horizontal at the end.

Skeletal structures were mapped out first, followed by the trachea and blood vessels, and the tracheostomy tube came last. Initially, the anatomical structures were just illustrated as if there were no tube present, with the tube in its own separate folder in Photoshop. The earlier stages didn't involve any heavy changes to the layout, but more feedback was received when the tracheostomy placement was factored in. (Figure 14)

While the provided image noted that the tracheostomy tube was placed between the second and third tracheal rings, an oversight led to the tube being placed between the first and second tracheal rings during the earlier stages. Aside from the location of the tube, feedback noted that the veins seemed a bit flat and two-dimensional and the trachea needed its color changed. Additionally, the tracheal tube was difficult to discern from the background and needed a strong outline to make it stand out, the mandible gave the impression that it was flat and needed some perspective on the underside to give it some dimension, and one of the tracheal rings needed to be removed. In these late stages of the illustration, this was the one that needed the most changes to meet the desired outcome.

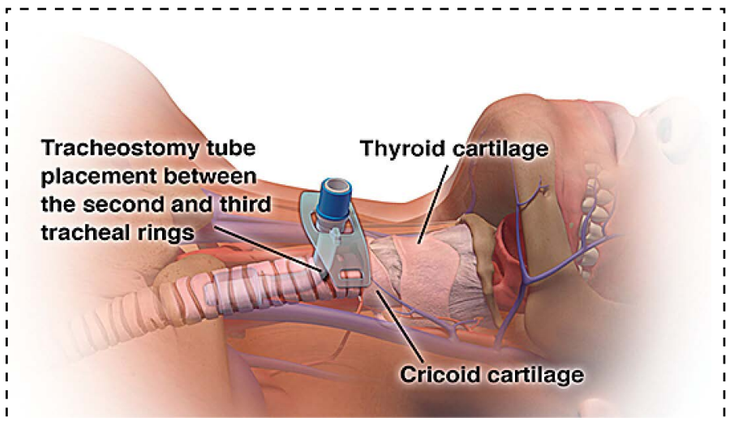
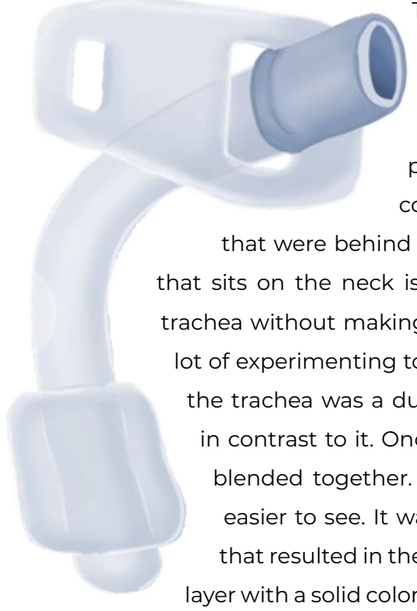


Figure 15: *Image of the tracheostomy provided by the TILT team. Copyright © by Massachusetts Medical Society*



The tracheostomy tube itself presented an interesting challenge compared to the other illustrations in the series, as it is not naturally a part of the human anatomy. While the tube's design was fairly straightforward, the difficulty presented itself regarding working with transparency and color. The tube needed to show all of the anatomical structures that were behind it while still being visible. When inserted, only the outer part that sits on the neck is visible. Depicting what it looks like as if positioned in the trachea without making it look like it was just sitting on top/overlaid on it needed a lot of experimenting to find something that would work. In the earlier stages when the trachea was a dull purple and pink hue, the blue color of the tube stood out in contrast to it. Once the color of the trachea was changed, the two somewhat blended together. The color of the tube was changed temporarily to make it easier to see. It was clarified that the tube also needed to be a blue-grey, and that resulted in the addition of a stronger white outline to make it more visible. A layer with a solid color in the shape of the part of the tube in the trachea was created on top with the multiply mode. This added the more shadowed appearance as if it were inside of the trachea instead of on top. (Figure 16)

Figure 16 (above): *Isolated image of the tracheostomy tube*

Final Detailing

After being exported as a PNG, two other versions – one without the tube (Figure 17) and one of the tube itself (Figure 16) – were also created to be used in the interactive resource. Before taking the completed illustration to Illustrator, the PNG was opened in Photoshop to adjust the orientation and positioning. The illustration was rotated on its side, and the liquify and puppet warp tools were used to slightly adjust the positioning of the head to make it tilted more forward. Unlike the other illustrations, this one did not have the shoulders or the entire head visible, so fading out the edges was approached differently, with it only applied to the left and right side of the adjusted illustration. (Figure 18)

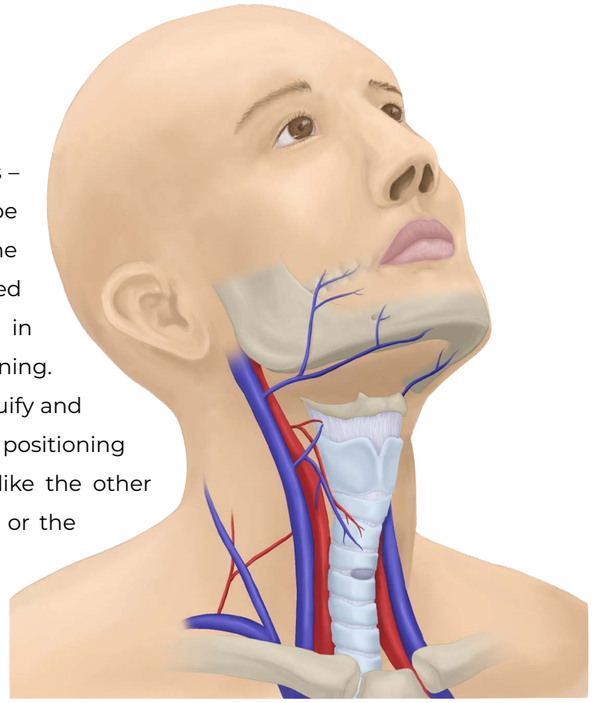


Figure 17: *Upright version of the illustration without the tracheostomy tube in place*

Once transferred to Illustrator, the three labels on Figure 15 were applied to the new illustration. These were done in Arial 40pt bold, with the lines in 4pt stroke weight. The outer glow effect was applied to the text and lines to make them stand out better against the illustration (as seen in Figure 20). A slightly varied labeled version was also created for the interactive resource.

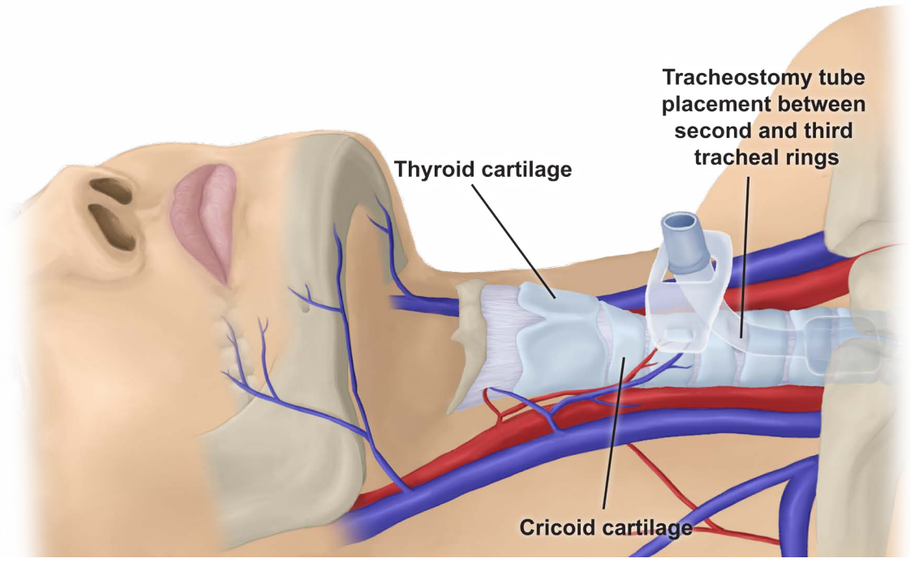


Figure 20: *Final Illustration labelled in Illustrator (For larger image, see Results section)*

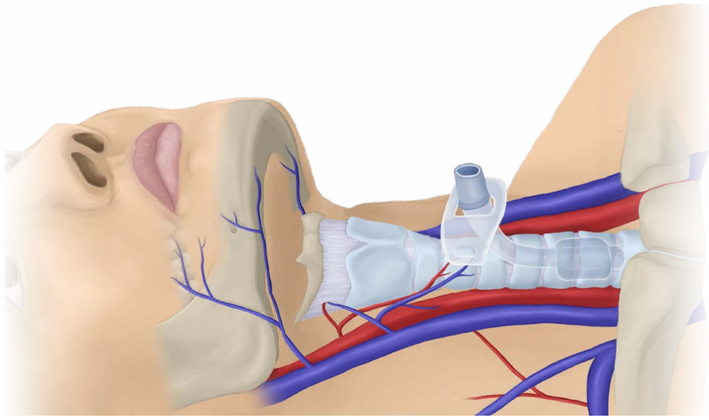


Figure 18: *Initial Tracheostomy illustration repositioned horizontally*

Another round of feedback post-rotation and labeling was given with the request to move the hyoid bone and trachea down lower on the neck and create a transparent overlay of the part of the sternum that would cover it. This task proved to be a bit difficult because of the way the layers were organized in Photoshop, and the method that ended up working best involved creating a merged layer of most of the structures aside from the sternum and clavicle. Using the move tool and liquify tool, the position of the trachea and surrounding structures were adjusted. It required a little bit of extra blending and going over more linework, but it was able to be adjusted as necessary. The jugular vein on the other side of the neck was added coming up behind the trachea and hyoid bone to connect the branching facial veins (Figure 19). Labels were then adjusted accordingly in Illustrator to reflect the tweaks to the image.

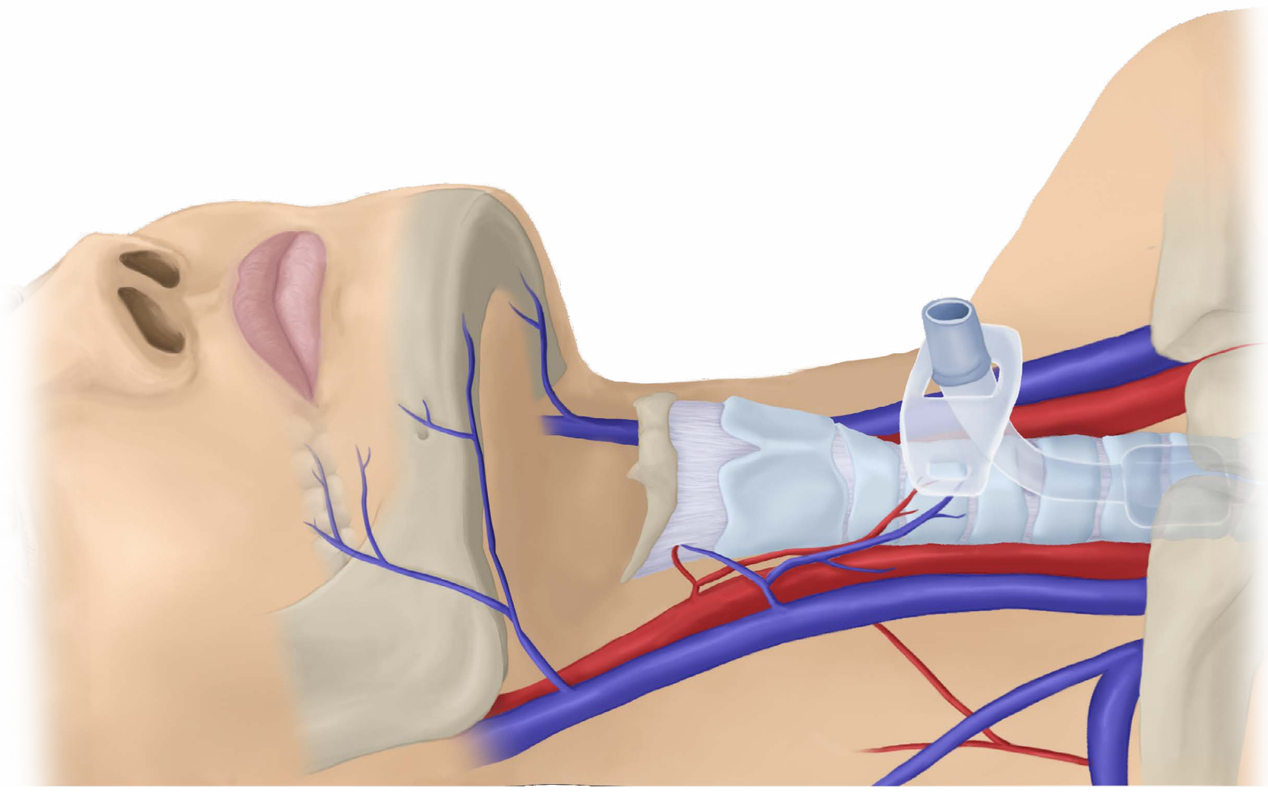


Figure 19: *Final Illustration with moved trachea positioning and sternum transparenct. Compare to* **Figure 18** *(pictured on top of page*

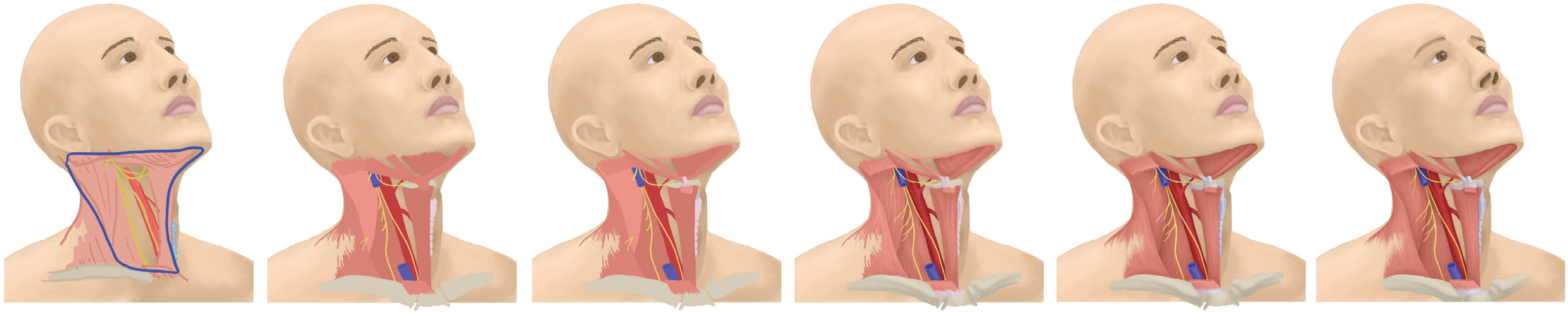
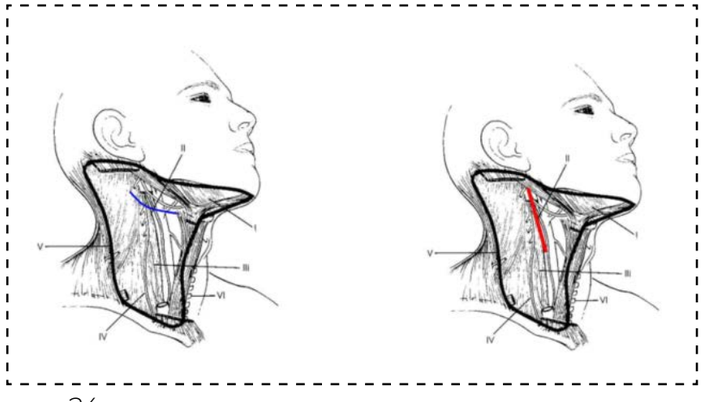


Figure 21: *Stages of progression for the neck compartments*

NECK COMPARTMENTS DEVELOPMENT

Out of the six illustrations initially provided, this one was the most difficult to interpret, as it was a very low resolution and was only black and white (Figure 22). Additionally, the labels were roman numerals with no legend. After a bit of research, a clearer image that was slightly different was found online (Figure 23), which was used to develop the initial stages of the illustration.

Like the anterior neck muscles illustration, the muscles on this one were created on different layers according to their depth in the neck. The sternum, clavicle, and hyoid bone were the same ones used in the tracheostomy illustration. As the amount of detail on the provided image was limited, early in the process it was difficult to identify the placement and appearance of certain muscles – specifically the digastric, stylohyoid, and omohyoid. These muscles appeared to be all converging into one at the hyoid bone, and that is reflected in the first stages of this illustration. After some clarification and feedback, it was amended with the proper organization of the structures as well as the addition of tendons to differentiate them more clearly. The trachea cartilage was also changed to grey-blue. (Figure 21)



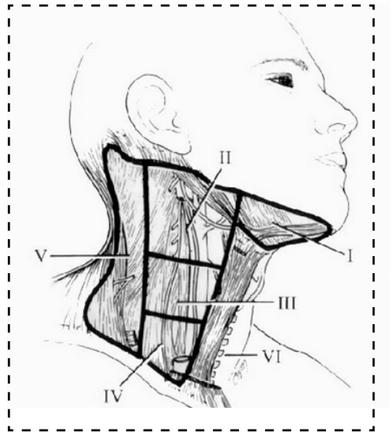
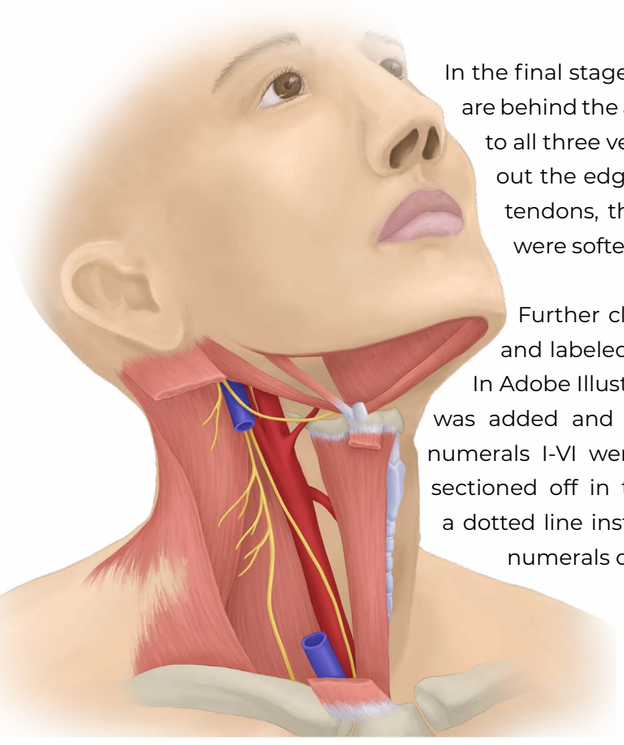


Figure 22 (left): *Image of the neck compartments provided by the TILT team.*
Figure 23 (above): *Clearer version found online.*



In the final stages, it was suggested to add more detail to the faces that are behind the anatomy overlays, resulting in further detail being added to all three versions. After adding some minor linework and blending out the edges of the clavicles and muscles and finer details on the tendons, the edges of the shoulders and upper part of the head were softened with the soft round pressure eraser tool. (Figure 24)

Further clarification on what specifically needed to be depicted and labeled were provided after the illustration work was finished. In Adobe Illustrator, an outline of the anatomical structures illustrated was added and using the original references as a guideline, roman numerals I-VI were added. The feedback requested that the areas be sectioned off in their specific divisions and outlined accordingly with a dotted line instead of a solid line, and a legend corresponding to the numerals on the side. (Figure 25)

The roman numerals are in 40pt Arial bold, and the text in the legend is Arial regular. Stroke weight is 3pt, to stay consistent with the rest of the diagrams. An un-labeled image with the dotted line sections was separately exported as well as six different versions with each compartment highlighted in green, which were used for the interactive module.

Figure 24 (above): *Final Illustration with no overlay*

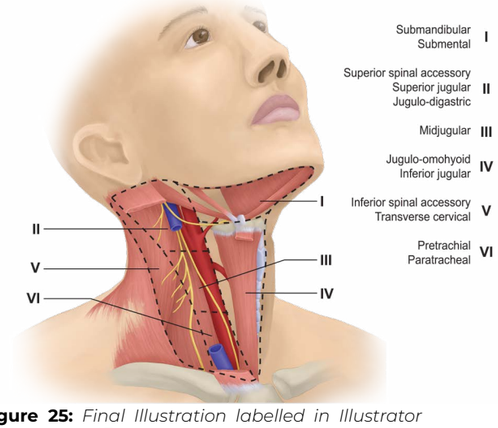


Figure 25: *Final Illustration labelled in Illustrator (For larger image, see Results section)*

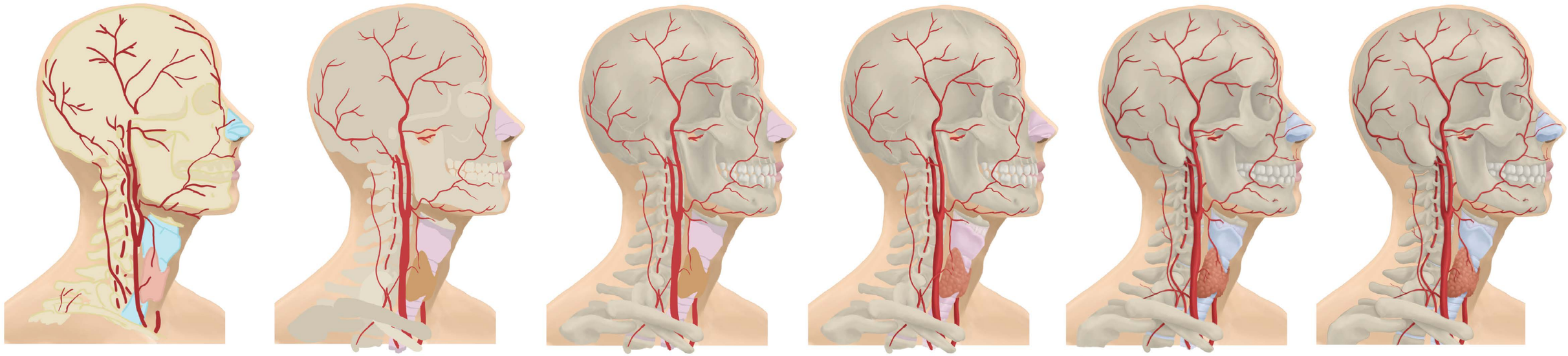
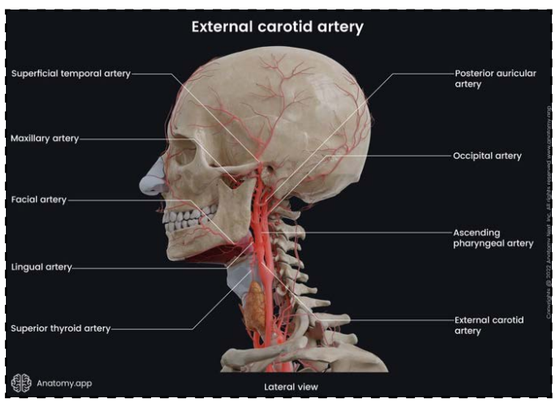


Figure 26: *Stages of progression for the carotid artery*

CAROTID ARTERY DEVELOPMENT

Two images for the carotid artery of the head and neck were initially provided, but it was clarified that they only needed one new illustration of the external carotid artery. As these initial images were of very high quality, the illustration process was relatively straightforward, with figuring out which minor arteries could be omitted being the main difficulty. Figure 27 labels more structures, while Figure 28 focuses specifically on the carotid sinus and the external and internal carotid arteries.

The beginning steps of this illustration focused on creating the skeleton, trachea, and thyroid, which were then followed by the artery placement. A lot of time went into ensuring that the skeleton was accurate with proper placement of notable structures. The skull, mandible, and spinal column were all on different layers to allow for any minor placement adjustments. The arteries were the final element to get added to the initial shape layout and the final structure to receive shading in the later stages. Shadows on the skull from the branching arteries were created by duplicating the layer, offsetting it slightly, setting it to multiply, and using gaussian blur to soften the edges. (Figure 26)



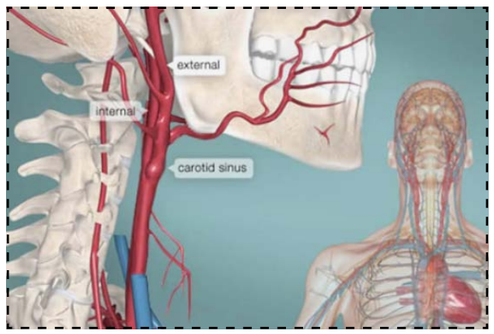


Figure 27 (left): *Image of the external carotid artery*
Copyright © by Anatomy Next, Inc.
Figure 28 (above): *Image of the major carotid artery parts*
Both provided by the TILT team

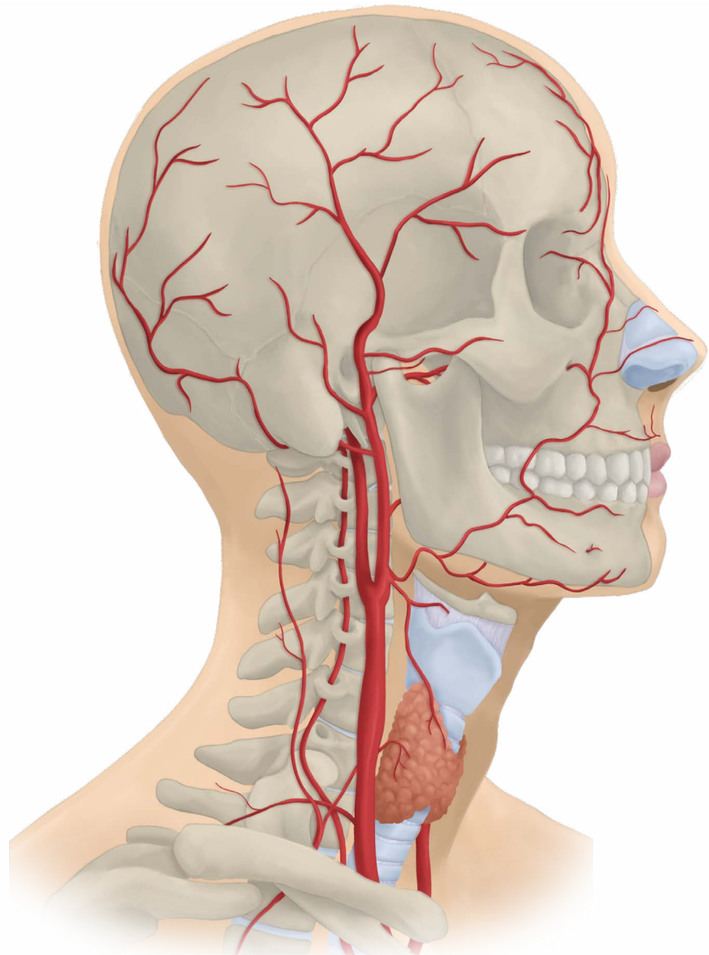


Figure 29: *Final carotid illustration*

There weren't any major changes that needed to be made. The trachea and nose cartilage were changed to grey-blue to match with the rest of the series. The occipital artery was modified to have it go behind the mastoid process and the posterior auricular artery was added as it was initially missed in the earlier stages. Feedback suggested that the skeleton have an outline to help differentiate it from the skin color of the background. The image was exported as a PNG and opened separately in Photoshop to add some transparency to the bottom edges of the illustration. (Figure 29)

Final Detailing

The final version was transferred as a PNG to Illustrator and had labels assigned with Arial 40pt type and 3pt stroke weight lines (Figure 30). Some isolated, zoomed in areas with slightly transparent shapes were created to show the placement of the maxillary artery, occipital artery, and ascending pharyngeal artery behind some of the skeletal structures. Those images were also exported as PNGs to use in the interactive resource (Figures 31, 32, 33).

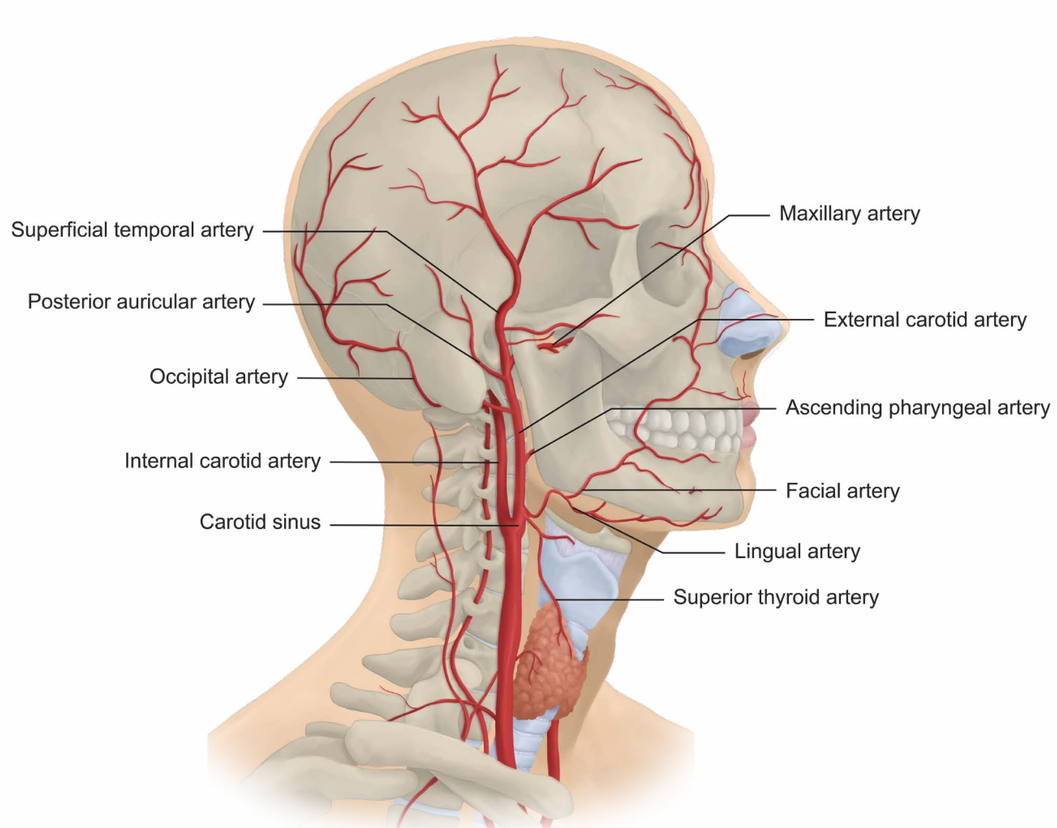
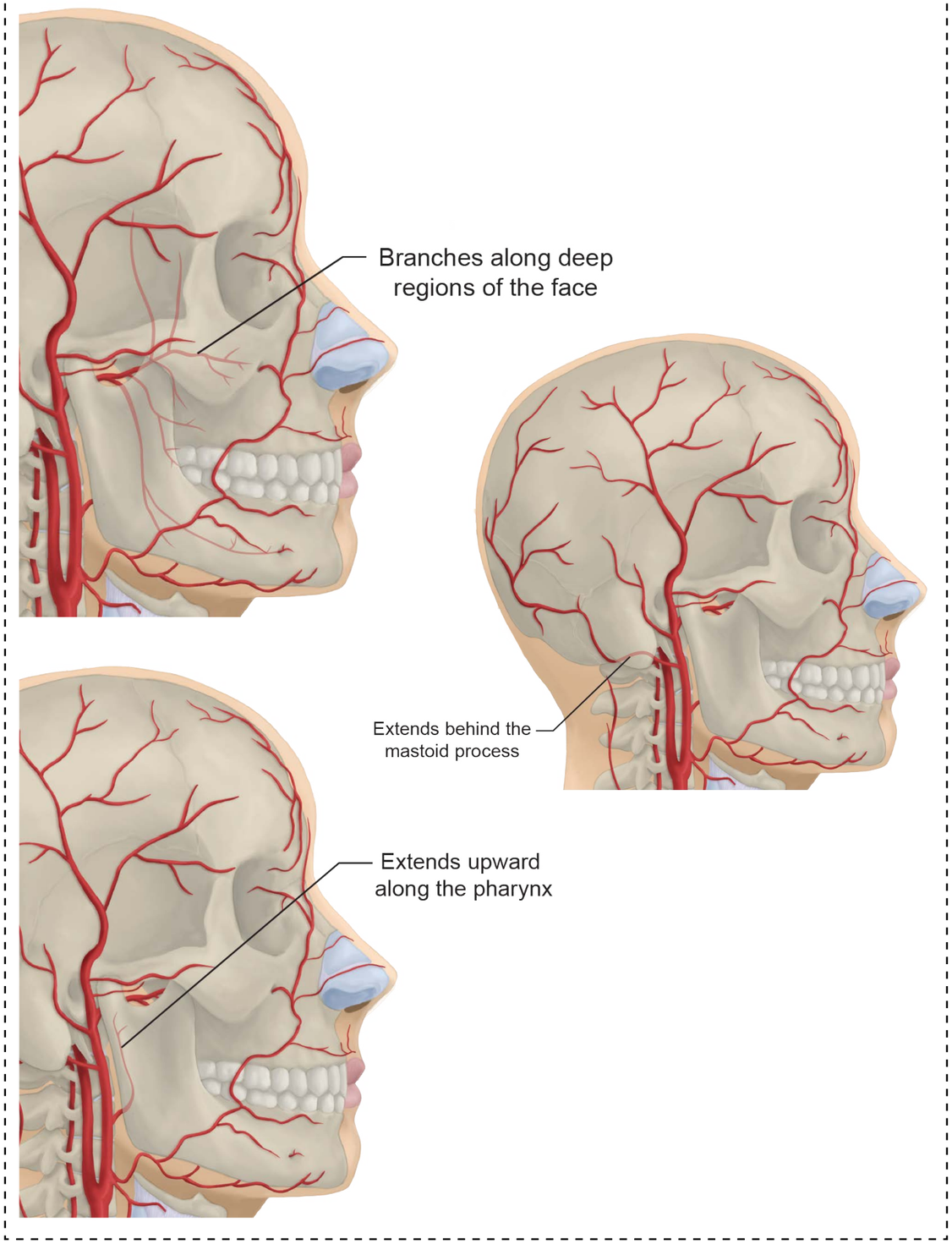


Figure 30: *Final Illustration labelled in Illustrator (For larger image, see Results section)*



Figures 31, 32, 33: *Close-up isolated labeled areas with transparent structures to communicate the deep arteries (Maxillary artery, Occipital artery, and Ascending Pharyngeal Artery)*

PARAPHARYNGEAL SPACE DEVELOPMENT

The parapharyngeal space is a difficult area to visualize, as it is in an area located deep within the anatomy of the head and neck. It is in the shape of an inverted pyramid, which makes it complicated to interpret on only one plane of orientation. For this reason, many other visual resources used for this area feature cross sections to better demonstrate the anatomy there. The illustration TILT provided shows where the area is located on the face but doesn't demonstrate the depth of the space itself. (Figure 35)

The initial base for this illustration was made using the same skull, mandible, and trachea assets that were used for the carotid artery illustration. A simple carotid artery and jugular vein were added, but they weren't a key focus of the image. The spinal column was added later in the process but is the same as the other one. An inverted triangle was created to block out the area visualized in the cross sections. The digastric, stylohyoid, lateral pterygoid, and styloglossus muscle were created using the different layer method the other illustrations use. The original idea for the highlighted area was to make the ramus of the mandible partially transparent, like the image that was originally provided. With the addition of muscles, the area highlighted seemed a bit busy and visually unclear. To better communicate the specific area where the parapharyngeal space is located, the inverted triangle was moved a few layers down to be behind the muscles and mandible. Since the space is deep in the facial anatomy, this change better communicates where the depicted area is. To clear up any possible confusion, the partially transparent area of the mandible was instead erased entirely and replaced with a dotted line to show its placement, giving a clear view of the inverted triangle. (Figure 34)

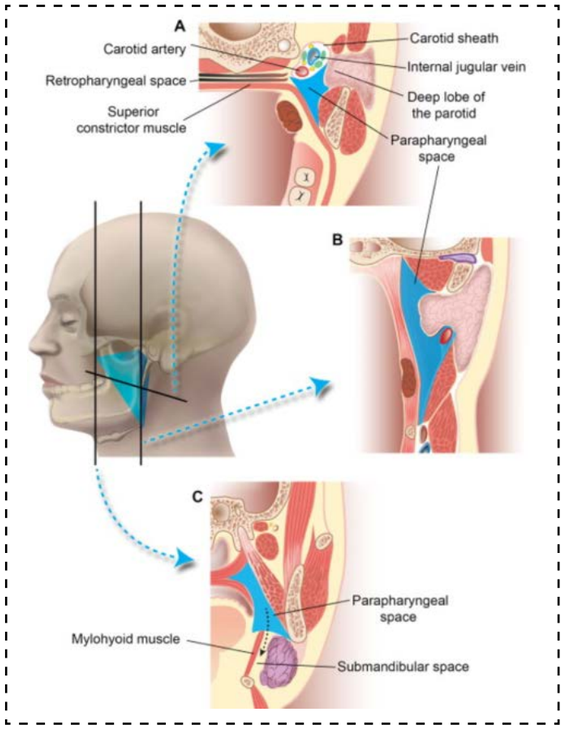


Figure 35: *Image of the parapharyngeal space provided by the TILT team.*

A cross-section line was originally depicted on the full head illustration in Photoshop but was later removed and replaced later in Illustrator. Since the focus of the illustration was the face, the shoulders and lower parts of the spine and trachea were blended and faded out to create a cleaner composition. This was then exported as a PNG to be transferred to Illustrator. (Figure 41)

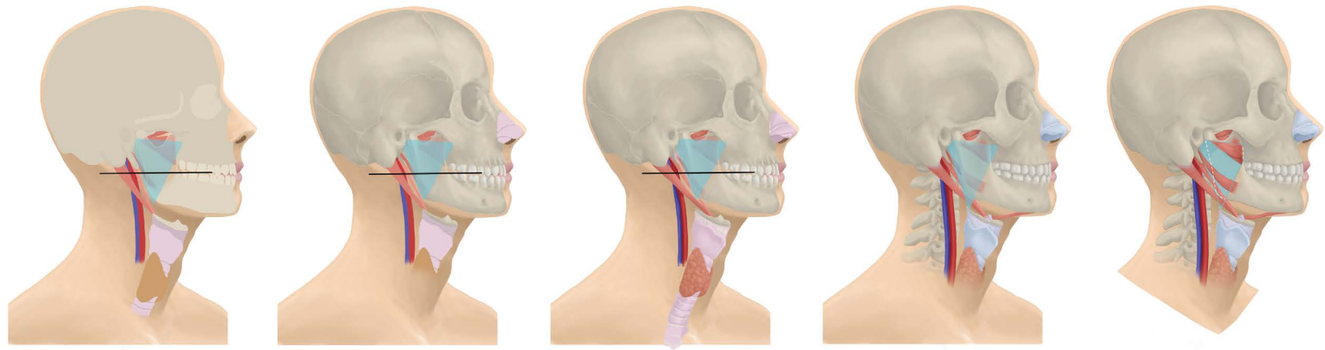


Figure 34: *Stages of progression for the parapharyngeal space head*

The cross sections – one on the sagittal plane and two on the coronal plane – were created in a separate Photoshop document. The process for these was much simpler than the stages of the head and neck illustrations. The cross sections were done in two stages, first the shapes, and then shading and texture. The colors used were taken from the same palette that the main series used. The texture for these was primarily created using the hard round pressure brush, while the main illustrations used the soft round pressure brush more heavily. The bone marrow texture was made with Kyle's Splatter Brush. The three cross sections were exported separately as PNGs. (Figures 36 & 37)

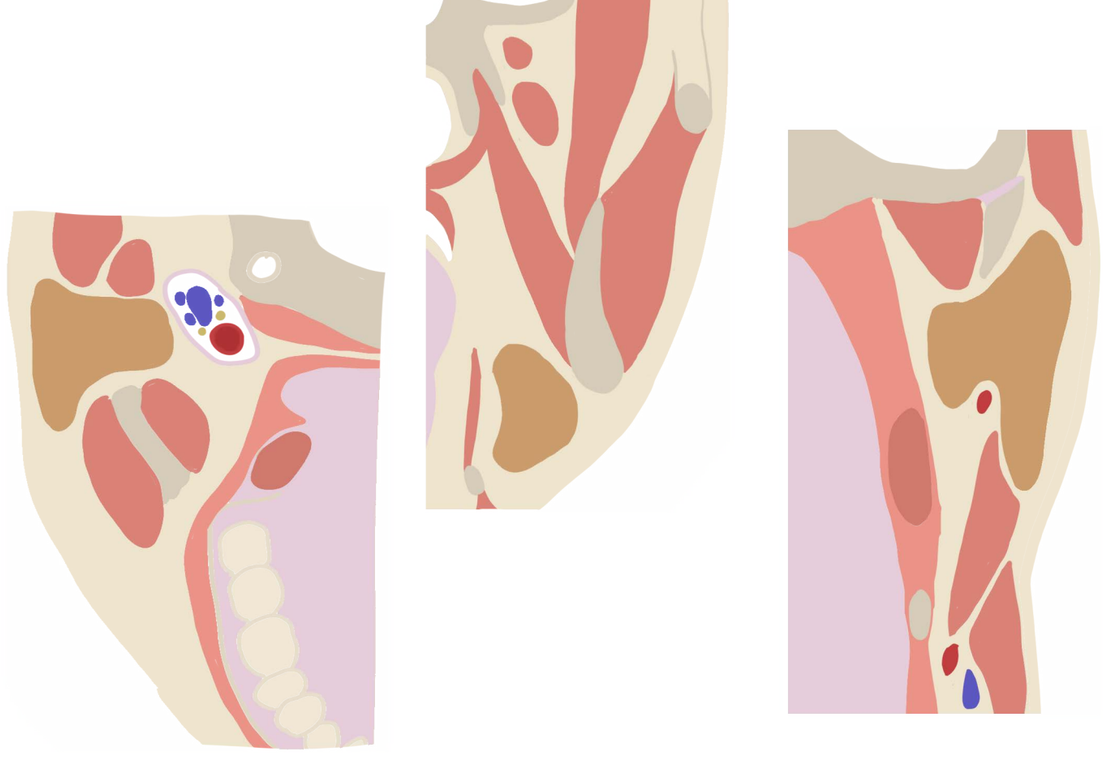


Figure 36: *Shapes/outlines for the parapharyngeal space cross sections*
The left one is the transverse slice, and the middle and right ones are coronal slices

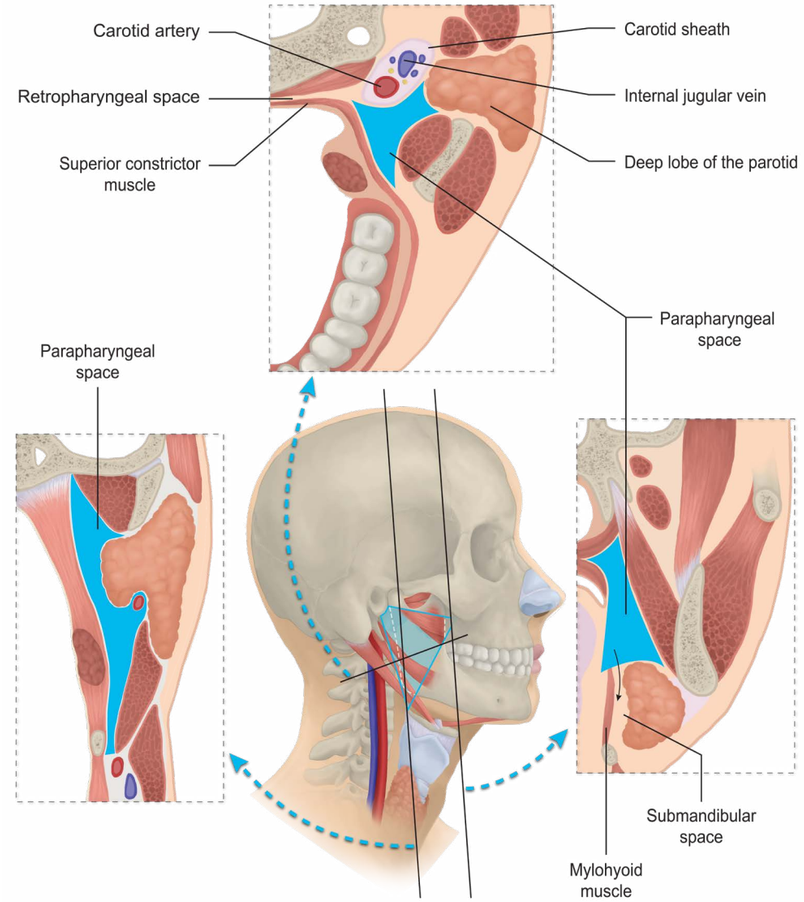
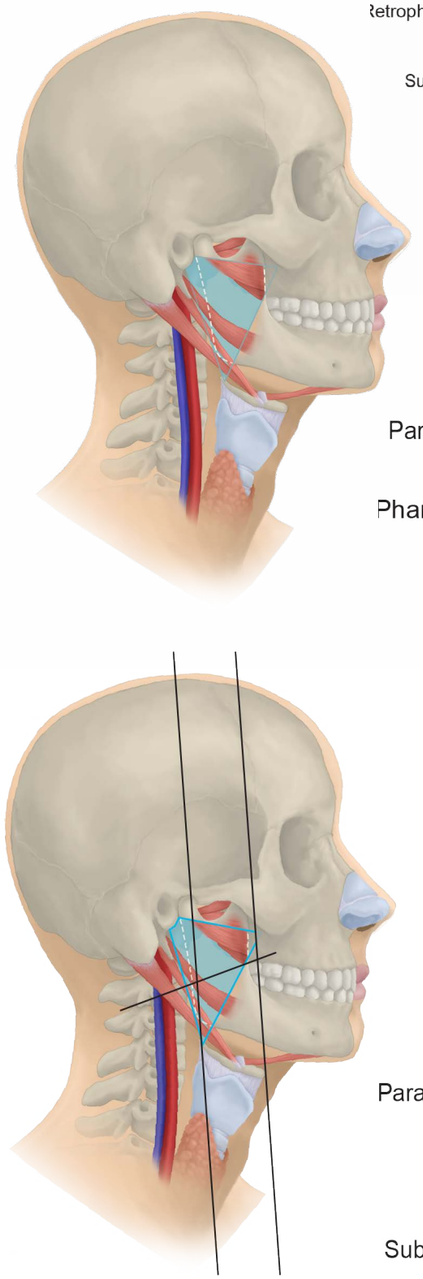


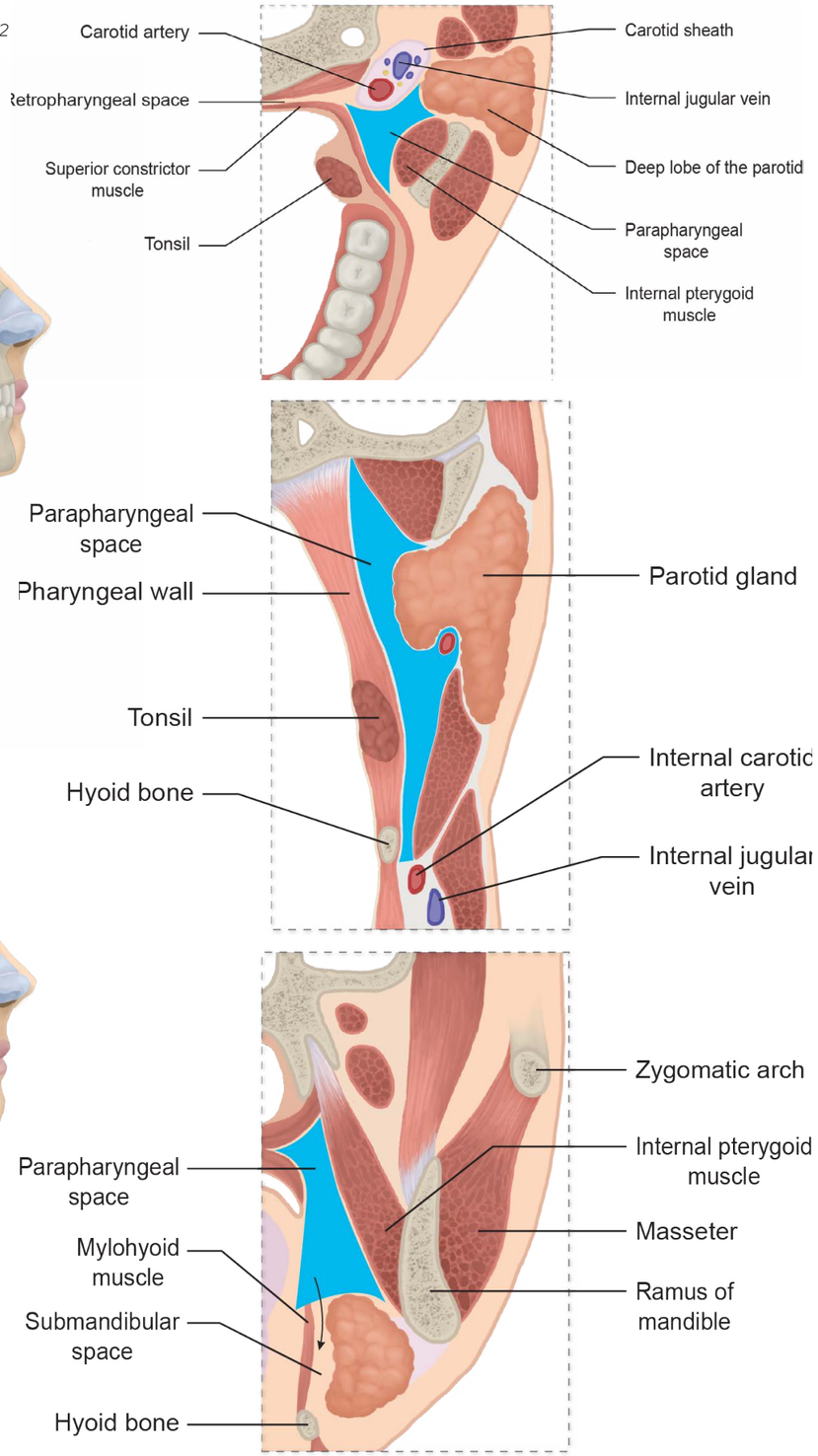
Figure 40: *Final Illustration labelled in Illustrator (For larger image, see Results section)*

Final Detailing

All four illustrations were placed together in one Illustrator document. Aside from the consistent 40pt Arial typeface and 3pt lines, three lines identifying the three cross section locations were drawn over the head illustration using the pen tool (Figure 42). The cross sections were put into boxes with grey dotted lines to define their edges. The areas of parapharyngeal space were then drawn out, also using the pen tool, using the blue color of the head's highlighted area. An 8pt dotted line was used to create three arrows, each pointing to a different cross section from their respective marked lines. A drop shadow effect was also applied to all the dotted lines to give them more dimension. The final full image was exported as a PNG (Figure 40). The labeled cross sections were also exported individually, with a few more notable structures labeled, for usage in the interactive module. (Figures 37, 38, 39)

Figure 41 (top) and 42 (bottom):
Un-labeled final illustrations, with 42 featuring cross-section lines





Figures 37, 38, 39: *Labeled cross sections used in the parapharyngeal space diagram and interactive module*

MAKING AN INTERACTIVE MODULE

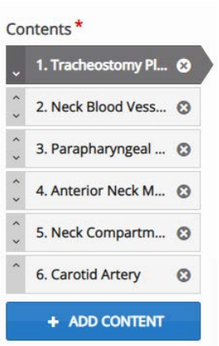


Figure 43: *Current activities listed in the module (editing mode)*

The interactive module was developed using Lumi Education and H5P. Lumi Education was chosen as the host platform as it is open-source and allows for the creation of interactive learning modules that are easily accessible. This tool is particularly helpful as it was designed for e-learning and has a user-friendly interface so that content can be created without the need for programming and coding skills. H5P is a content collaboration plugin that uses JavaScript and HTML to create and share content. Lumi Education supports the H5P plugin, which allows users to make their learning modules interactive.

This module was created using the H5P content compiler, which allows for multiple types of H5P activities. All the current activities in the content compiler for this module are the Hotspot content type, but by creating the module in a content compiler, further activities beyond just hotspots (i.e., flashcards, quizzes, interactive videos) can be added to the module as well. (Figure 43)

The H5P Hotspot content type was used to make the illustrations interactive. Hotspots are locations on an image that can be clicked to reveal an overlay that can feature images, videos, and text. Using the Lumi Desktop application, the un-labeled versions of the illustrations were each imported as their own activity. The hotspots are placed at various distinct locations on the illustration, and the popup features the name of the structure, with certain ones including more textual information or a supplemental image or diagram.

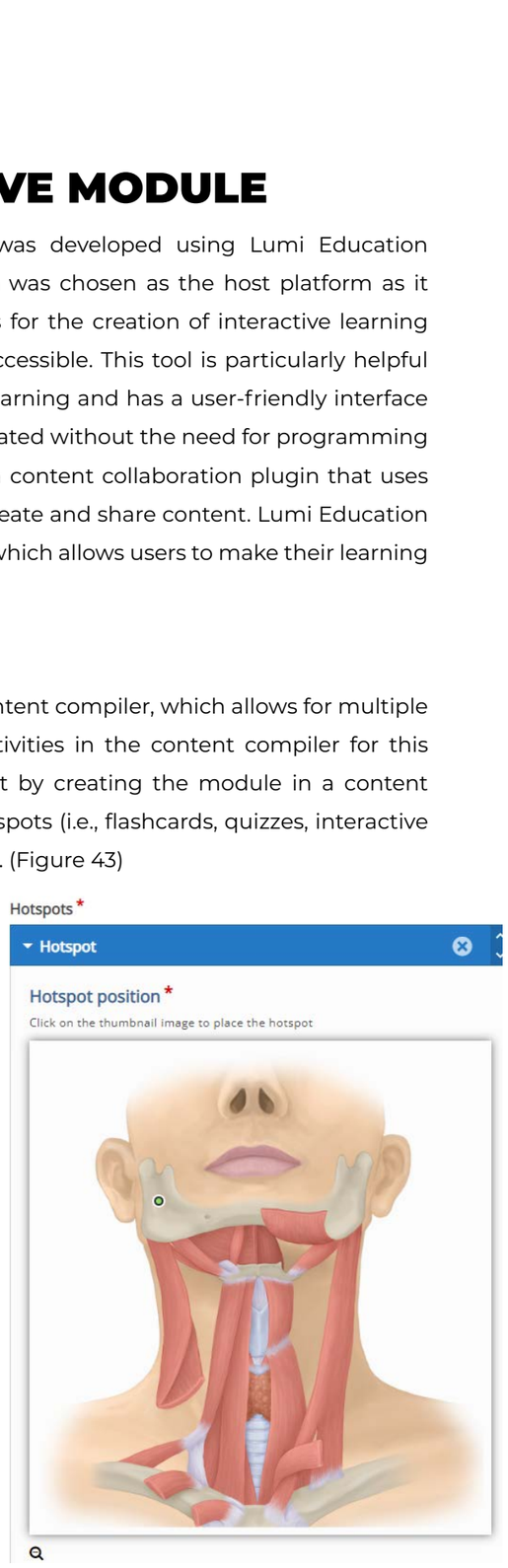


Figure 44: *Interface used to select a location to attach a hotspot. Pictured hotspot being placed is on the mandible*

The hotspot placement and information were based off the labeled versions of the illustrations and features extra images and diagrams of the tracheostomy tube and placement, minor veins and arteries, and cross sections of the parapharyngeal space (Figures 44, 45).

Lumi Cloud allows for the publishing of content that can be accessed on web-based platforms or downloaded to use offline on Lumi desktop. Once published, the module can be accessed through the Lumi platform, as well as offering the ability to make it available through a QR code, link, or embedded on a website. The H5P content compiler allows for easy filtering of activities based on tags and keywords, which can be beneficial for future additions to the resource.

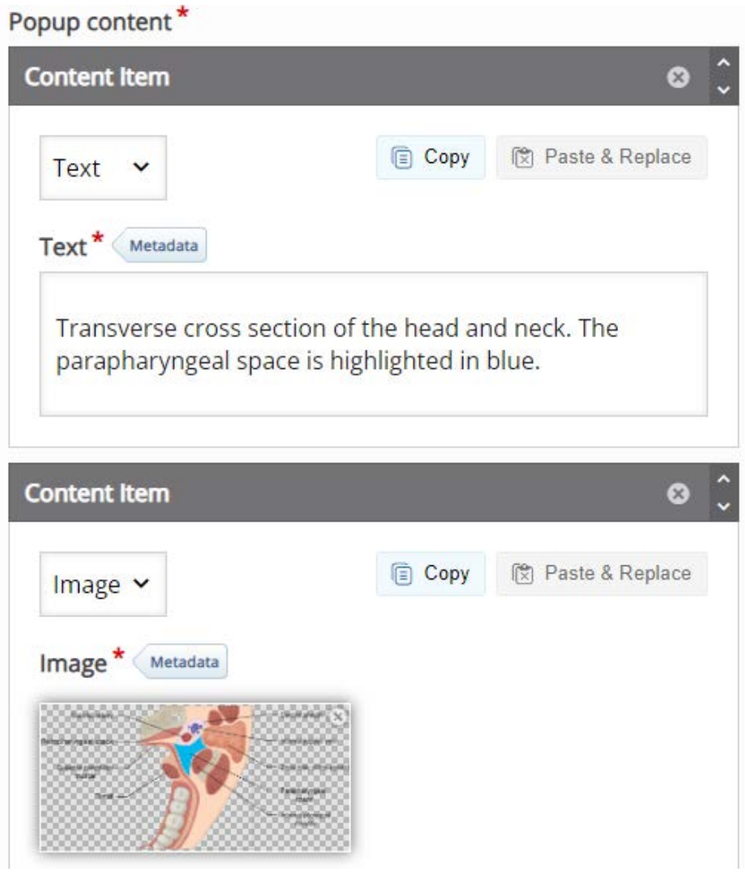


Figure 45: *Interface used to add options like text, images, and other media once a hotspot location is selected*

RESULTS

The resource outcome for this project included a series of head and neck illustrations that were used in textbook-style labeled anatomical diagrams and an interactive online learning module.

The illustrations produced consisted of the anterior neck muscles, veins and arteries around the trachea and thyroid, anatomical location and placement of a tracheostomy tube, the divisions of compartments of the neck, the external carotid artery, and a visualization of the parapharyngeal space. These illustrations were individually labelled for usage as still images/diagrams.

INTERACTIVE MODULE

The interactive learning module was created and published using Lumi Education and is free to access. The module opens with a brief introduction statement about the purpose of the module and what it contains. The user is then taken to a page with the six illustrations listed as different activities (see Interactive Module Final Outcomes), showing a thumbnail of the illustration and a description of what it's for. When selected, a full-size image of the corresponding illustration that is dotted with green circles is brought up. The user can interact with each individual circle, and clicking one brings up a pop-up with that structure's label. The pop-up pages for the tracheostomy tube and placement, minor veins and arteries, cross sections of the parapharyngeal space, and some more complex muscles feature extra information and supplemental diagrams. These help with further clarification on the location of some of the hotspots, which is helpful for muscles with different sections, structures that are mirrored on both sides, and for supplying additional information not directly depicted in the main illustration.

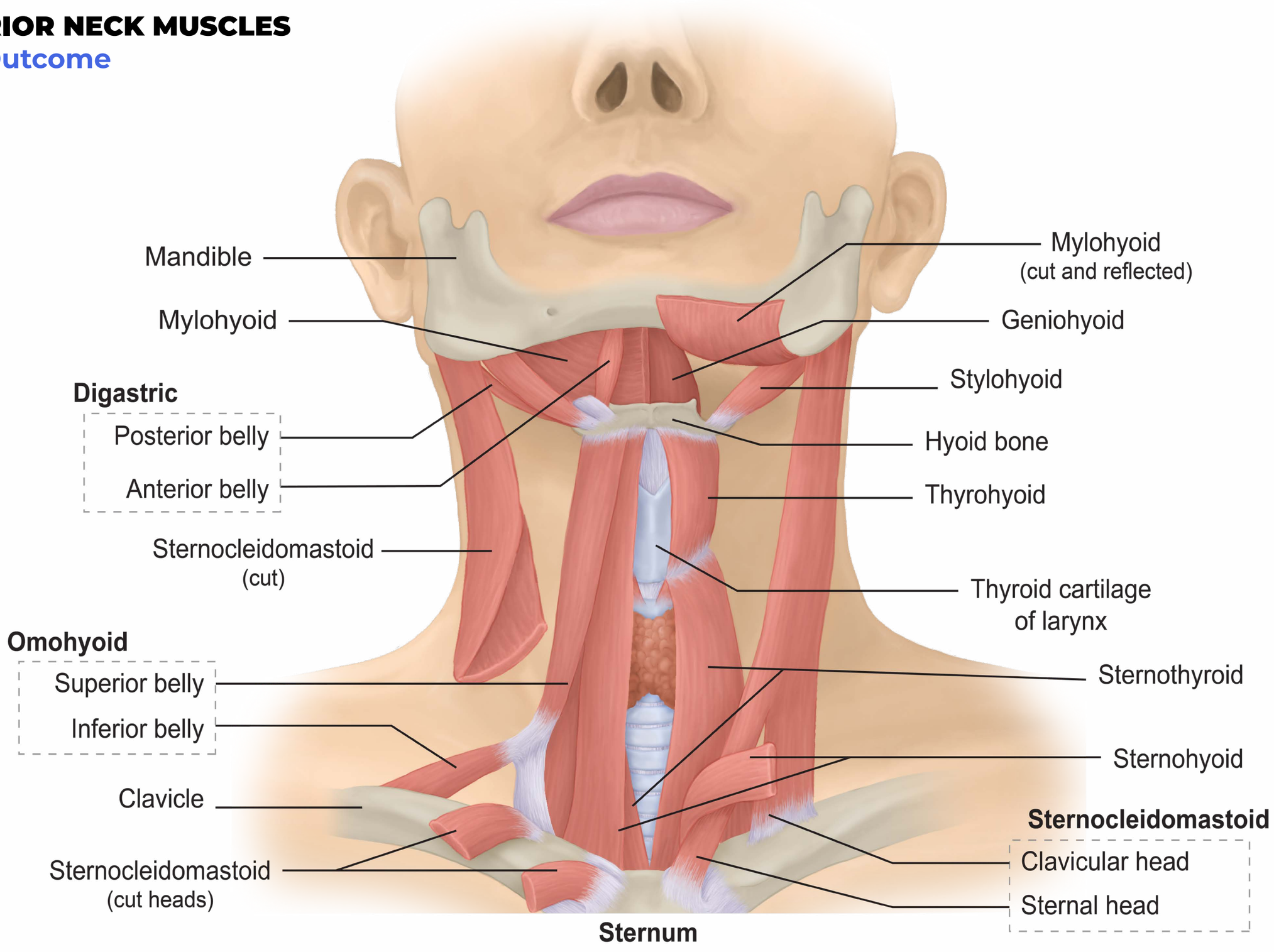
Online Module QR Code and Link

https://app.Lumi.education/run/yhpROw

Interacting with the QR code or link will direct the user to a webpage with the learning module through Lumi Cloud. This page is accessible to anyone who uses the link or scans the QR code. Any further content added to this module will become available to users as well.

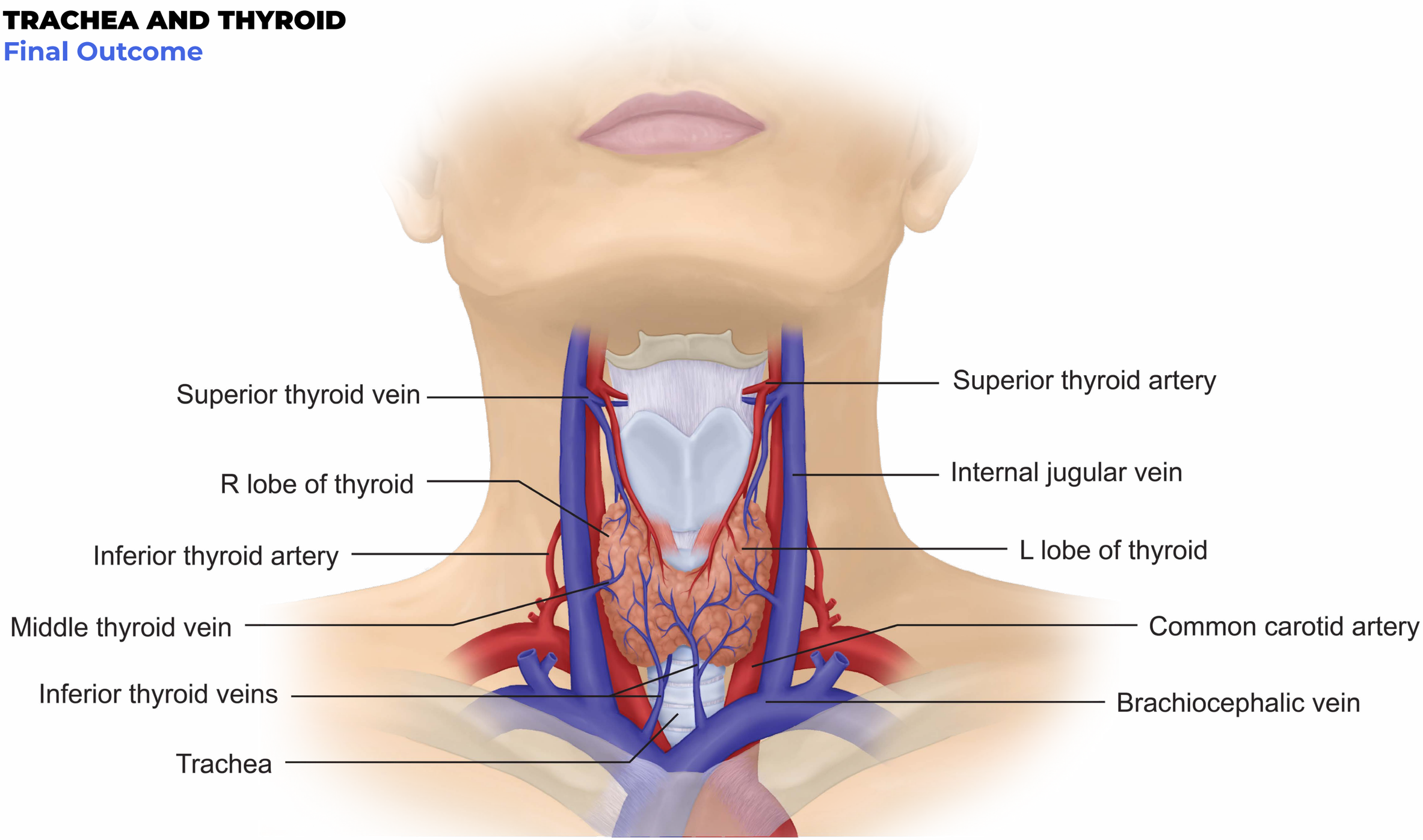
ANTERIOR NECK MUSCLES

Final Outcome



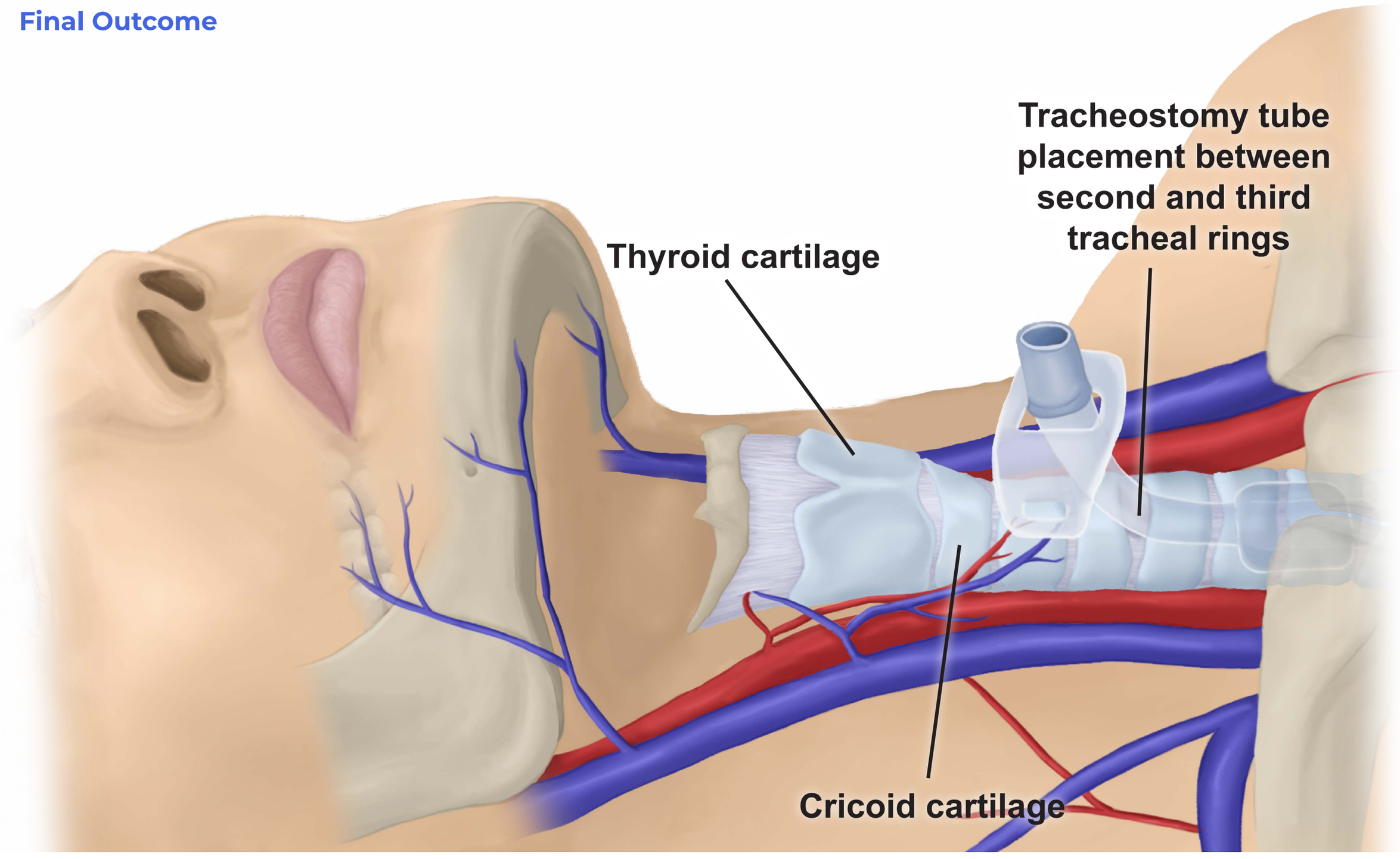
VEINS AND ARTERIES OF THE TRACHEA AND THYROID

Final Outcome



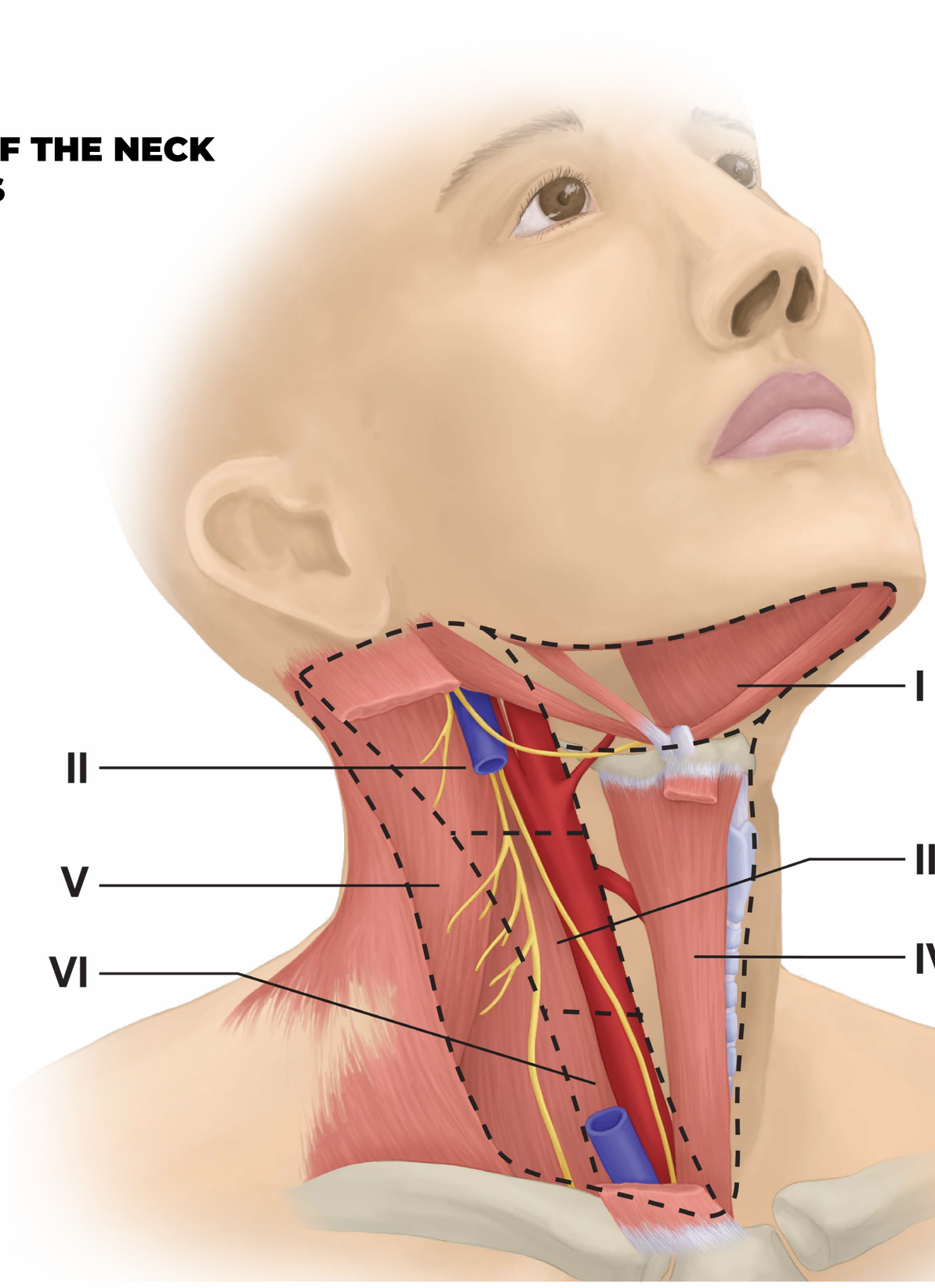
PLACEMENT OF A TRACHEOSTOMY TUBE

Final Outcome



SUBDIVISIONS OF THE NECK COMPARTMENTS

Final Outcome



Submandibular
Submental — **I**

Superior spinal accessory
Superior jugular
Jugulo-digastric — **II**

Midjugular — **III**

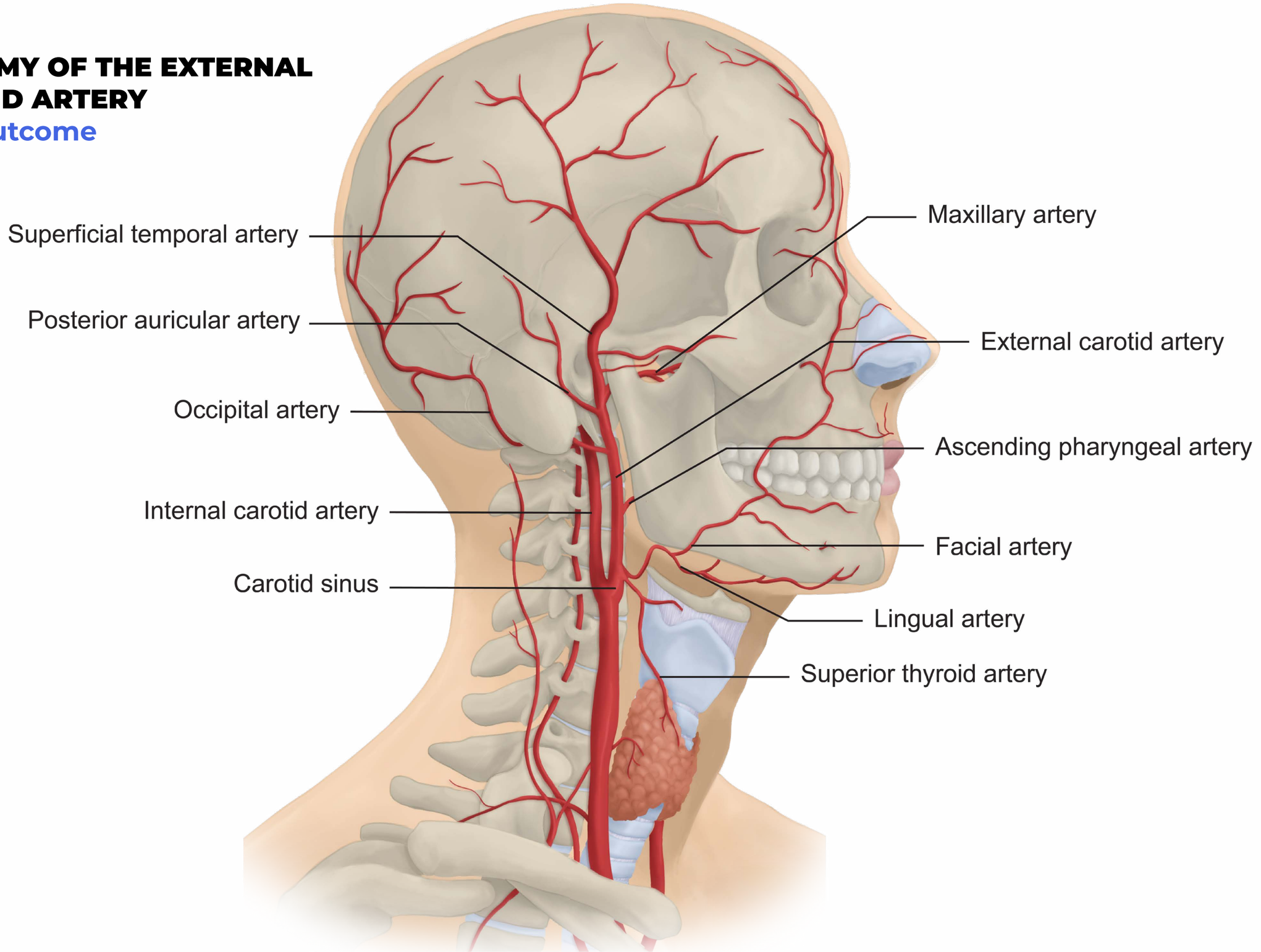
Jugulo-omohyoid
Inferior jugular — **IV**

Inferior spinal accessory
Transverse cervical — **V**

Pretrachial
Paratracheal — **VI**

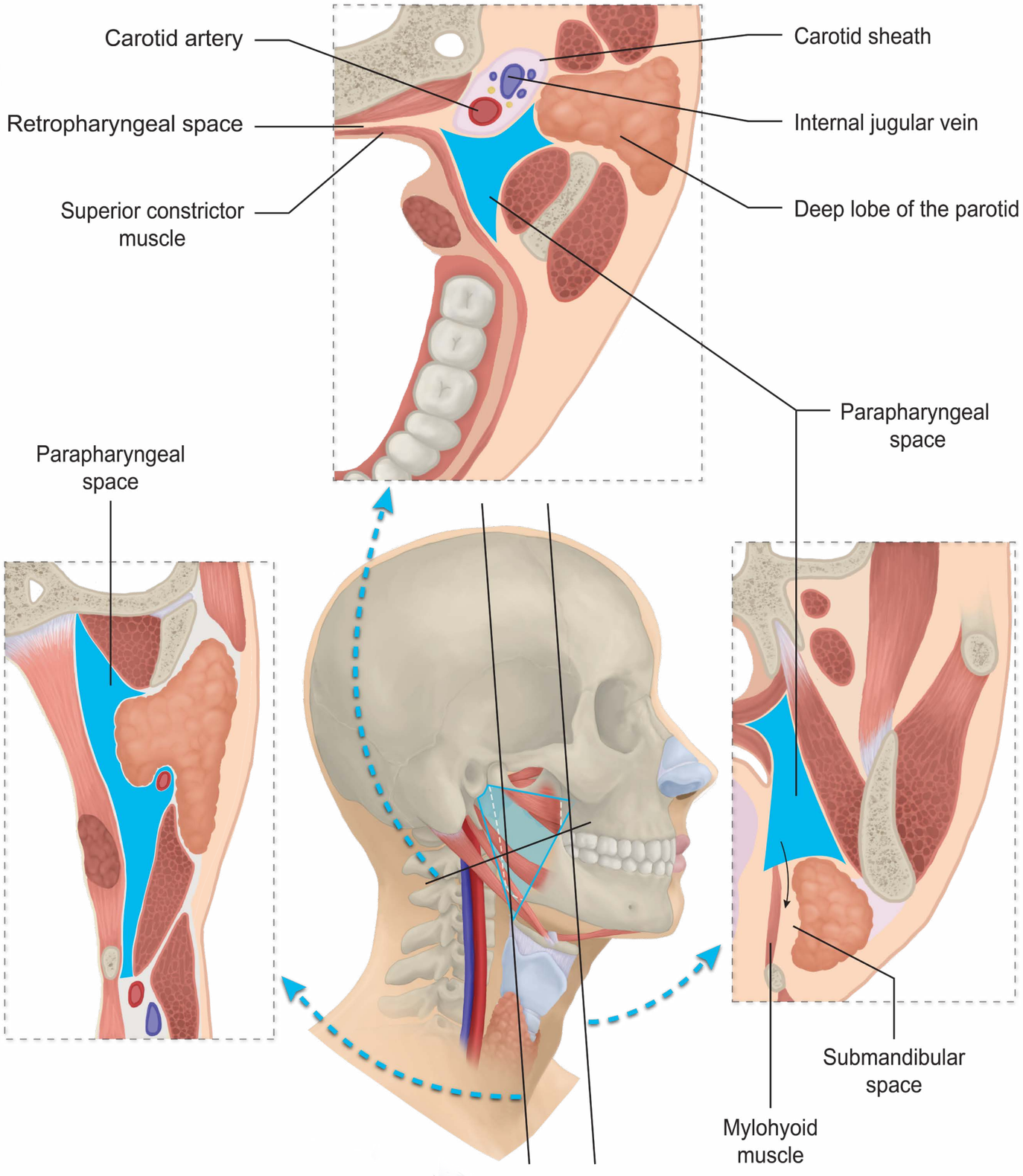
ANATOMY OF THE EXTERNAL CAROTID ARTERY

Final Outcome



VISUALIZATION OF THE PARAPHARYNGEAL SPACE

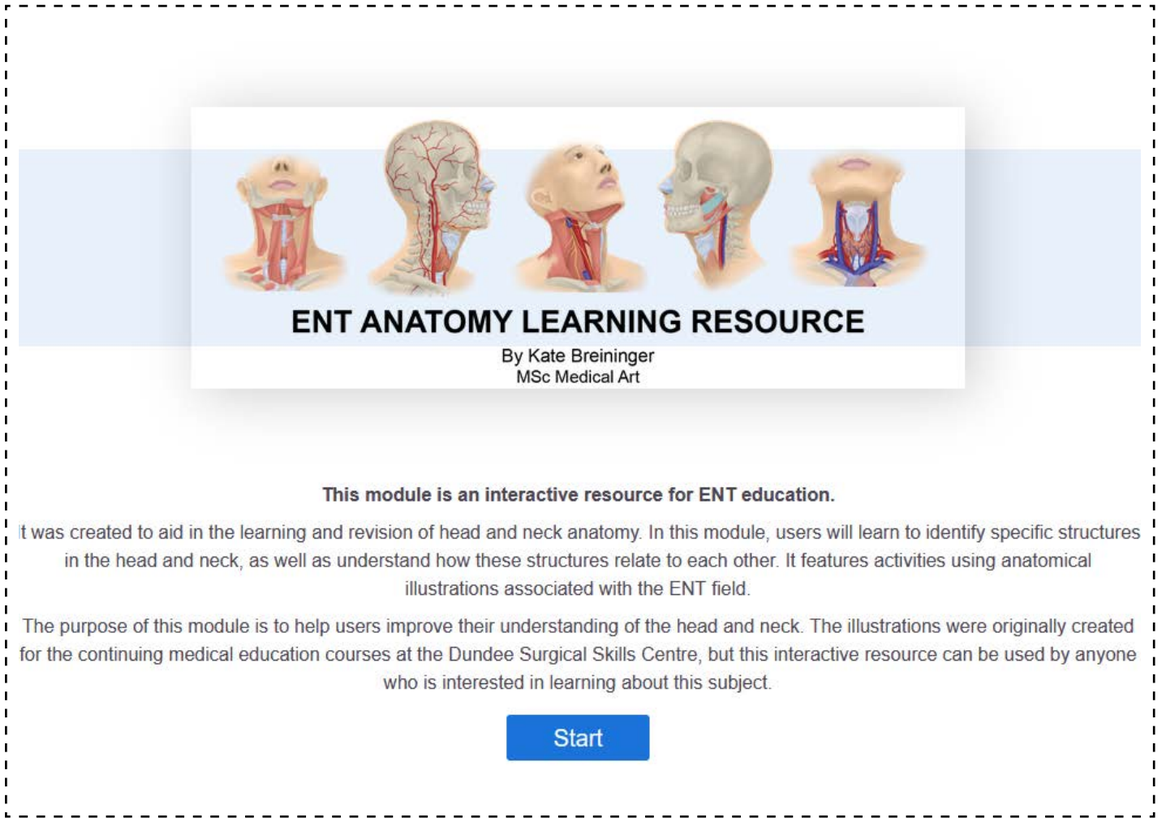
Final Outcome



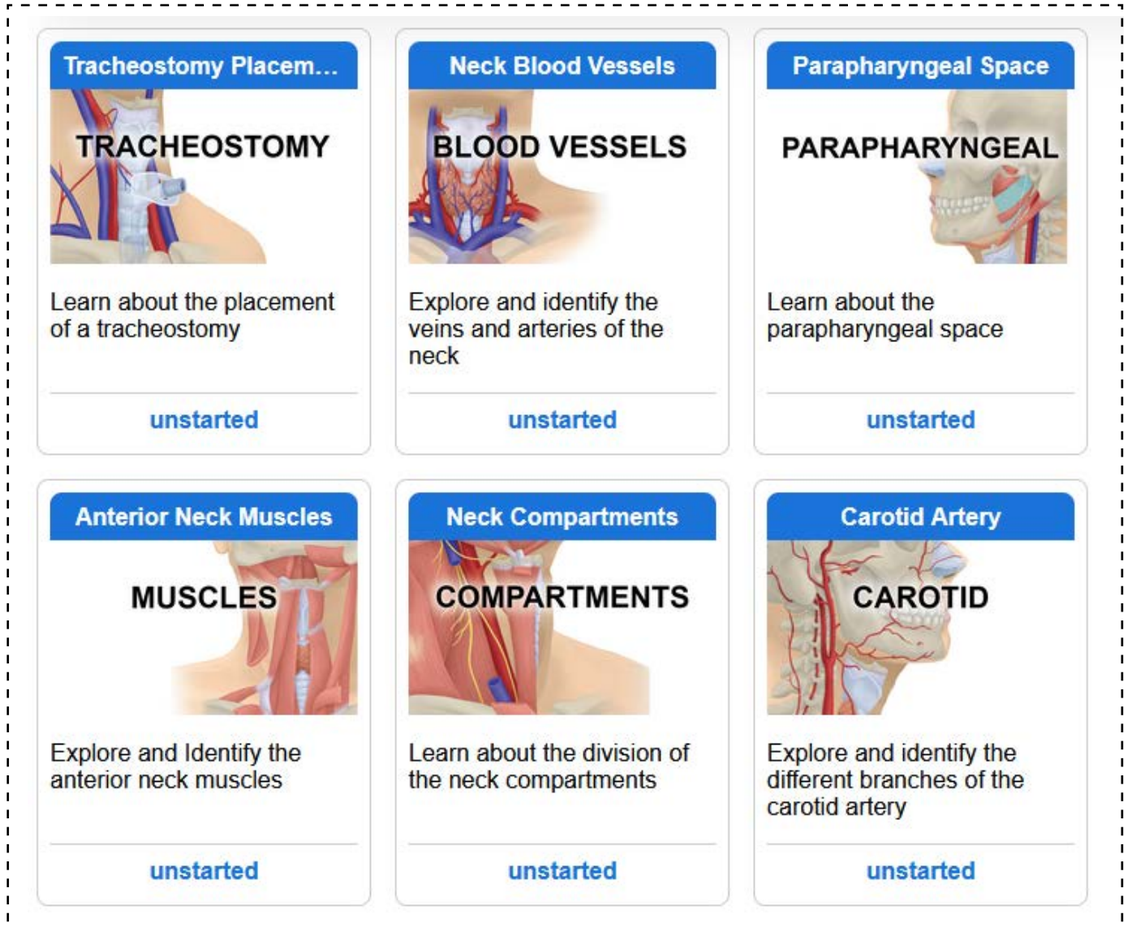
INTERACTIVE MODULE

Final Outcome

Screenshots of the Lumi resource from a user perspective



Introduction Page



Activity Selection

INTERACTIVE MODULE

Final Outcome

Examples of the Hotspots activity

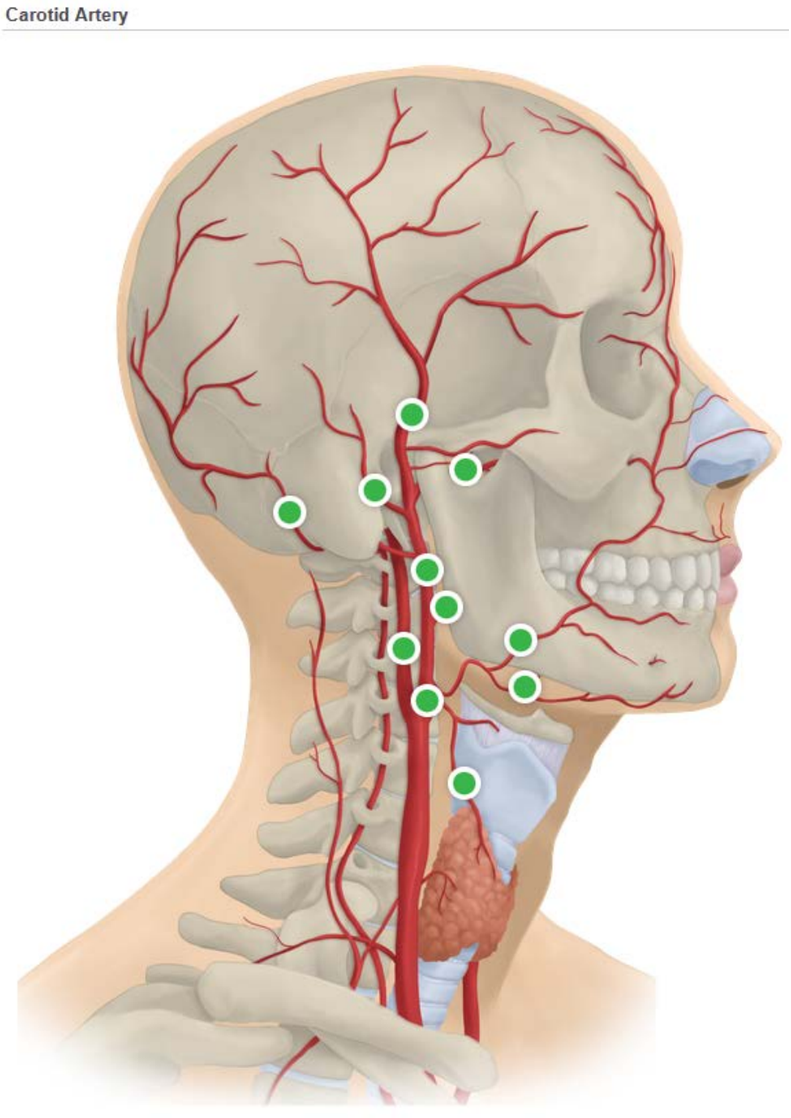
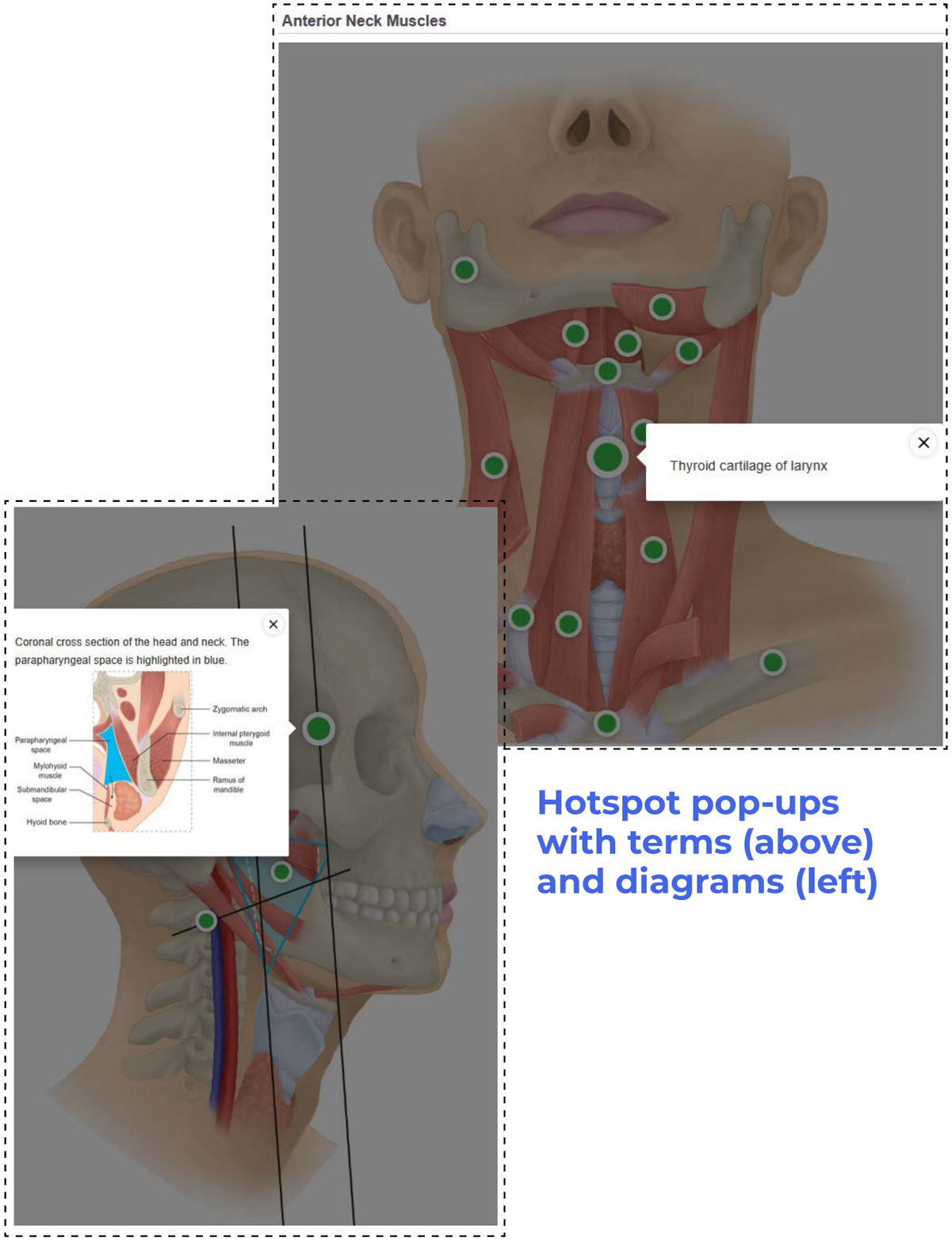


Illustration with multiple interactive Hotspots (green circles) attached



Hotspot pop-ups with terms (above) and diagrams (left)

DISCUSSION

The original objective of this project was to develop a consistent series of illustrations for ENT specialists to use in their continuing medical education. The illustrations themselves do not have specific uses and can be used for any course that needs a visual diagram related to its subject. For this purpose, the illustrations will optimally be viewed alongside other supplementary materials as a resource to aid with revision.

The interactive module was developed with the accessibility of information in mind. While the original illustrations were created for usage for the courses at the Surgical Skills Centre at the Dundee Institute of Healthcare Simulation, the lack adequate ENT education students receive presented the opportunity to create a resource to improve that. The aim of the interactive module is to help students learn to identify and understand the complex structures presented, rather than only being used for revision.

Whether used as supplemental information or as a standalone resource, having access to a consistent series of illustrations can be beneficial to both students and professionals. This project can benefit from future development and the addition of more illustrations. The user-friendliness of H5P can make the creation of further interactive additions easier. The aim of this resource is to be informative and understandable, allowing for an adequate level of knowledge transfer, which can be improved as the available visual materials are expanded upon.

The strengths of creating this resource are represented in the accessibility of high-quality, consistent imagery in the illustrations, which are presented with their respective informative labels. Current limitations involve the lack of variation in interactive activities, which may affect the learning experience of the online module. This resource can benefit from further development of more illustrations or different H5P activities. User feedback would be beneficial in expanding these activities to include more engaging ways of communicating information and giving access to more visual materials. The H5P content compiler can be used to incorporate more ways of communicating information aside from anatomical illustrations and can even provide surveys for collecting user feedback. New modules can also be developed for other medical fields beyond the ENT specialization.

CONCLUSION

Among this project's aims was to improve understanding of head and neck anatomy and create accessible learning materials for it. Medical illustrations play a prominent role in medical education, and consistent resources can help improve one's understanding of complex anatomical structures. 2D illustrations have always been a part of medical illustration, and it is important to keep them up to date, even with the development of 3D models. By creating this series of illustrations, and subsequent interactive module, it allows for learners to access a wider variety of learning materials for their learning experience. The illustrations were developed in multiple stages with multiple rounds of feedback from professionals to ensure anatomical accuracy, and even if they are used as standalone diagrams without the rest of the series, they still clearly communicate their respective information. While originally only intended to be a collection of more traditional textbook-style labeled illustrations for usage by the Surgical Skills Centre, the creation of the Lumi module expands the accessibility of this work to a larger audience. Access to the internet has increased the quality of education and the availability of learning resources, and this project was created to add to that. The available resources online may be more heavily saturated with some subjects like the carotid artery and neck muscles, but other more specific subjects like the parapharyngeal space or tracheostomy placement may have a limited variety of visual materials available. This resource can help to expand upon those limited resources while also providing imagery for the more common ones in a consistent illustration style, which can increase one's overall understanding of how they relate to each other. Learning outcomes have been proven to improve with the usage of interactive learning methods and by creating interactive materials designed to engage learners beyond just viewing an illustration, more knowledge can be retained. While currently only limited to six illustrations and hotspot-style interactive activities, this resource has the potential to impact learning and revision for both students and professionals.

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IMAGE INDEX