“Hold Your Breath and Bear Down”: Using Valsalva’s Maneuver to Explore Venous Variations in the Neck

Rachael K. Krinke and Shayla D. Yoachim

Corresponding Author: shayla.yoachim@unmc.edu

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"Hold Your Breath and Bear Down": Using Valsalva's Maneuver to Explore Venous Variations in the Neck

Rachael K. Krinke, BS[1] and Shayla D. Yoachim, PhD[2]

[1]University of Nebraska Medical Center College of Dentistry, Lincoln, NE

[2]Department of Oral Biology, University of Nebraska Medical Center College of Dentistry, Lincoln, NE

Corresponding author: shayla.yoachim@unmc.edu

Abstract

The remarkable variation in superficial veins of the neck challenges anatomy students during cadaveric exploration. Despite frequently serving as cannulation sites, conduits for catheter placement, grafts following carotid endarterectomy, and a visual representation of central venous pressure, the jugular venous network and its variations are not well elucidated. A lack of health care provider awareness of venous variation may increase risk of clinical complications including ecchymosis, necrosis, and increased intraoperative bleeding. This study integrates an exploration of superficial venous variation in the necks of cadaveric specimens with a simple living anatomy exercise for anatomy students, aimed to shed light on anatomical variation and the typical venous patterns students may encounter in lab and clinically. Cadaveric dissections were completed on twenty-four specimens to identify common variations from the textbook venous pattern of the neck and 3D renderings were created to help students better visualize anomalies. Next, students were instructed to perform the Valsalva maneuver to distend venous structures in the neck for visualization; photographs were taken to demonstrate the range of visible structures and patterns in living subjects. Four patterns were identified via cadaveric exploration and illustrated via three-dimensional (3D) renderings, and subject photographs were used to enhance learning by engaging students in the prediction of underlying structures. This activity deepened students' appreciation for anatomical variation and promoted awareness needed for pre-interventional planning. https://doi.org/10.21692/haps.2022.018

Key words: anatomy teaching, gross anatomy education, living anatomy, anatomical variation, experiential learning, Valsalva maneuver, jugular veins

Introduction

Variations in venous drainage are frequent in humans, especially in the head and neck region. Because traditional anatomy atlases demonstrate only the most common anatomical pattern, students taking a cadaveric anatomy lab may struggle to recognize variations from the norm. Knowledge of frequently occurring variations is important to all anatomy students for identification purposes, and especially for those who may become health care providers. This would be particularly important if they were providing treatment in the head and neck regions of the body; this would include head and neck surgeons, oral and maxillofacial surgeons, anesthesiologists, and radiologists (Silva et al. 2016). The network of jugular veins is particularly important for catheterization, central venous pressure monitoring, and intravenous infusions; these veins may also be used for venous grafts (e.g., patch for carotid endarterectomies), or included in microvascular anastomoses for oral reconstruction (Gupta 2003; Silva et al. 2016; Singh 2020).

For example, the common facial vein has been used as patch material in carotid endarterectomies for decades and more recently recognized as an alternative route for catheter placement (Abeysekara et al. 2008; Bertha and Rabi 2011; Umek and Cvetko 2019). In addition to surgical needs, the increased administration of neurotoxins (Botox) and dermal fillers in the neck to relieve fine lines and wrinkles requires an acute awareness of superficial venous structures to avoid potential complications such as ecchymosis and necrosis (Lee et al. 2019). While numerous studies have reported isolated examples of venous anomalies in the neck, few have attempted to classify typical patterns (Bertha and Rabi 2011; Dalip et al. 2018; Sanyal and Joeaneke 2020).

Despite the heterogeneity of the vascularity in the neck, the traditional anatomical texts describe the typical superficial venous drainage as follows (e.g., Figure 3A as presented in the Results section). Venous drainage of the lateral scalp occurs via the superficial temporal vein, which unites with the maxillary vein to form the retromandibular vein within the substance of the parotid gland. The retromandibular

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vein typically divides almost immediately into anterior and posterior divisions, with the anterior division uniting with the facial vein to form the common facial vein, which subsequently drains into the internal jugular vein. The posterior division of the retromandibular vein merges with the posterior auricular vein to form the external jugular vein, destined to drain into the subclavian vein in the root of the neck.

Numerous studies have described frequently occurring anomalies of this venous drainage pattern. For example, the external jugular vein is sometimes absent unilaterally or bilaterally, causing superficial veins to drain directly into the deeper internal jugular vein (Dalip et al. 2018; Paraskevas et al. 2014). There have also been cases noting duplication of the external jugular vein either unilaterally or bilaterally (Comert and Comert 2009; Ono et al. 2021). Additionally, even more variable is the anterior jugular vein, which may be a single midline vein or two parallel veins draining either into the external jugular vein or the subclavian vein (Lee et al. 2022; Nayak 2006). Finally, the common facial vein shows considerable variation in presence, length, and drainage tributary (Gupta 2003; Silva et al. 2016; Singh 2020). Few studies to date have reported typical lengths of individual's common facial vein, despite the necessary consideration when evaluating its potential for catheter placement or harvesting graft material (van Tonder et al. 2021). Given this remarkable variation in superficial venous drainage and the awareness required for clinical care, identifying veins of the neck and atypical variations is crucial, yet may be challenging, for anatomy students and clinicians alike.

Recent reports by Dee et al. (2021) and Georgakarakos and Fiska (2022) have revealed deficits in current anatomy teaching practices in instilling 'authentic learning' related to vascular anatomy, with the result that both undergraduate and resident students lack the clinically and surgically oriented knowledge of vascularity required to appreciate anatomical variations so that they can modify treatment plans when necessary. 'Authentic learning' in anatomical education requires intentional pedagogical approaches of high intrinsic value and clear translation to clinical application (Pawlina and Drake 2016). Surface anatomy is a fundamental component of health professional training to prepare students to visualize superficial anatomical landmarks in the living patient (Abu Bakar et al. 2022; Ganguly and Chan 2007). As an exercise to complement traditional anatomy pedagogy (lectures and laboratory), the incorporation of 'living anatomy' exercises enhances students' abilities to solidify practical aspects of anatomical knowledge by observing, palpating, and manipulating their peers (Aggarwal et al. 2006; Jensen 2016; Johnson et al. 2012; Metcalf et al. 1982).

As one component of living anatomy, surface anatomy assessments can be done without any required equipment by simple demonstration, and the students themselves can serve as the subjects in the activity with their peers. This type of peer examination allows students to experience the inspection, palpation, and manipulation that a patient experiences, and may help them to develop empathy for others (Abu Bakar et al. 2022; Chinnah et al. 2011; Metcalf et al. 1982). When integrated into anatomical education, surface anatomy training has been shown to improve knowledge retention and assessment scores (Johnson et al. 2012). Clinically oriented surface anatomy exercises have long been recognized as important in anatomy education by increasing student confidence in translating knowledge to clinical skills (Aggarwal et al. 2006; Chinnah et al. 2011; Johnson et al. 2012). As rising costs in higher education create economic strain and limit resource expenditure, it is crucial to develop affordable or no-cost educational resources and activities to engage students (Price 2020).

One conventional maneuver that can be used to produce venous distension for better surface visualization is Valsalva's maneuver, in which a patient is asked to forcefully attempt to exhale against a closed airway (Gupta et al. 2003; Pstras et al. 2016). Antonio Maria Valsalva, the Italian anatomist and physician, first described this technique in 1704 as a means to encourage purulent drainage from the ear (Kumar and Van Zundert 2018). Since then, the maneuver has been used clinically to evaluate autonomic dysfunction, identify and treat arrhythmias, and as a marker for heart failure (Junqueira, 2008; Kumar and Van Zundert 2018; Pstras et al. 2016).

This non-invasive technique causes an increase in intrathoracic pressure and reduced venous return to the heart, which in effect distends the neck veins allowing to better visualization of these procedurally important vessels (Pstras et al. 2016; Solanki et al. 2018). Although Valsalva's maneuver has been a common method for producing venous distension in the clinical environment, it has not yet been described as an educational 'living anatomy' technique for students learning the superficial veins of the neck. As a simple, quick exercise, incorporating this 'living anatomy' experience for student observation may foster real-life application of venous anomalies while instilling an appreciation for the considerable anatomical variation encountered in clinical settings.

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Previous studies conducted on small cohorts of anatomical donors have revealed remarkable variation in drainage patterns, and considerable variation in the mere presence of all tributaries discussed therein (Dalip et al. 2018; Karuppiah and Ponnambalam 2020; Ono et al. 2021; Silva et al. 2016). Given the wide variation reported, we aimed to contribute another data set to expand the reported variations in cadaveric specimens and classify frequently occurring superficial patterns. Furthermore, because previous studies that emphasize three-dimensional visualization of anatomy structures increases student understanding, we created 3D renderings of the most common variations we encountered for students to access outside the anatomy lab (Shaia and Elzie 2019). Because the common facial vein, in particular, has been of noted importance for clinical use with regard to catheter placement and graft potential, we also measured the length of each common facial vein encountered (Abeysekara et al. 2008). Finally, we introduced a simple living anatomy exercise to our anatomy students while exploring the superficial neck in cadaver lab, asking students to perform the Valsalva's maneuver for their peers to observe 'real-life' variations and classify the visualized patterns if possible. Our goal was to shed light on the remarkable variation of superficial venous drainage in the neck both by cadaveric exploration and a living anatomy exercise in peer-to-peer observation, thereby elucidating a simple means by which students can gain an appreciation of both anatomical variation and awareness of non-invasive techniques to aid in visualization of anatomical variation.

Materials and Methods

The Institutional Review Board at the University of Nebraska Medical Center (UNMC) approved this study in 2020 (#0877-20-EP). Eighteen human cadavers, obtained through Nebraska's Deeded Body Program with consent given for educational and research use, were dissected by UNMC health professional students and faculty and observed for data collection. Each hemi-specimen was recorded individually and for those specimens in which both sides were available, the two sides were inspected for symmetry. 15 left and 9 right hemi-specimens had viable, intact venous tributaries; the remaining specimens had incomplete or compromised dissections. After inspection of venous pattern, the length of each common facial vein (CFV) was measured using calipers by both researchers and the average length recorded. Simultaneously, all students currently enrolled in the Head and Neck Anatomy course participated in the living anatomy exercise by performing the Valsalva maneuver (taking a deep breath and holding it while bearing down to increase intrathoracic pressure). Twenty students volunteered and gave consent to be photographed while doing so. Photographs of each hemi-neck were taken for future inspection, capturing peak visibility of each subject's distended superficial veins.

Results

Classification of cadaveric venous patterns

15 of the 24 specimens (62.5%) had a facial vein (FV) and anterior division of the retromandibular vein (ARMV) uniting to form the common facial vein (CFV) that drained into the internal jugular vein (IJV), the pattern most often depicted in anatomical texts; we therefore call this category 1 (Figure 1A). 14 of those 15 in category 1 had the typical union of the posterior division of the retromandibular vein (RRMV) joining the posterior auricular vein (PAV) to form the EJV. The remaining specimen in category 1 lacked an external jugular vein (EJV) entirely. Two specimens had a FV and ARMV combine to form the CFV which drained into the EJV; this pattern we call category 2 (Figure 1B). Six specimens lacked a CFV, and four of those showed the FV and RMV combining to form the EJV directly (no RMV divisions visible); this arrangement is category 3 (Figure 1C). Another single specimen had the FV and ARMV combine to form a lengthy CFV which ran adjacent to the AJV, both draining into the EJV at the root of the neck; this is called category 4 (Figure 1D).

While 22 of our 24 specimens fell into these four categories, we also observed two variants rarely reported; these are considered 'other' in Figure 2. One specimen had the FV and ARMV draining into the AJV. The remaining single specimen had the FV and ARMV uniting with the IJV independently. Six full cadavers had sufficient intact tissue structure to compare the left and right sides for symmetry. Of the six, four cadavers were symmetrical across midline in their venous patterns. The average length of the CFV was 34.0mm (range = 8 mm to 112 mm). Representative dissections are shown in Figure 1A-D, and Figure 2 summarizes the cadaveric findings by proposed category.

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Figure 1. *Examples of cadaveric dissections demonstrating variations in superficial venous structures. A. Typical pattern of FV combining with ARMV to form CFV which drains into the INJ. B. Variation in which the CFV divides into two segments, both of which drain into the EJV. C. FV and RMV combine to form the EJV, with no communication to the IJV. D. Atypical long CFV runs adjacent to AJV to drain into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)*

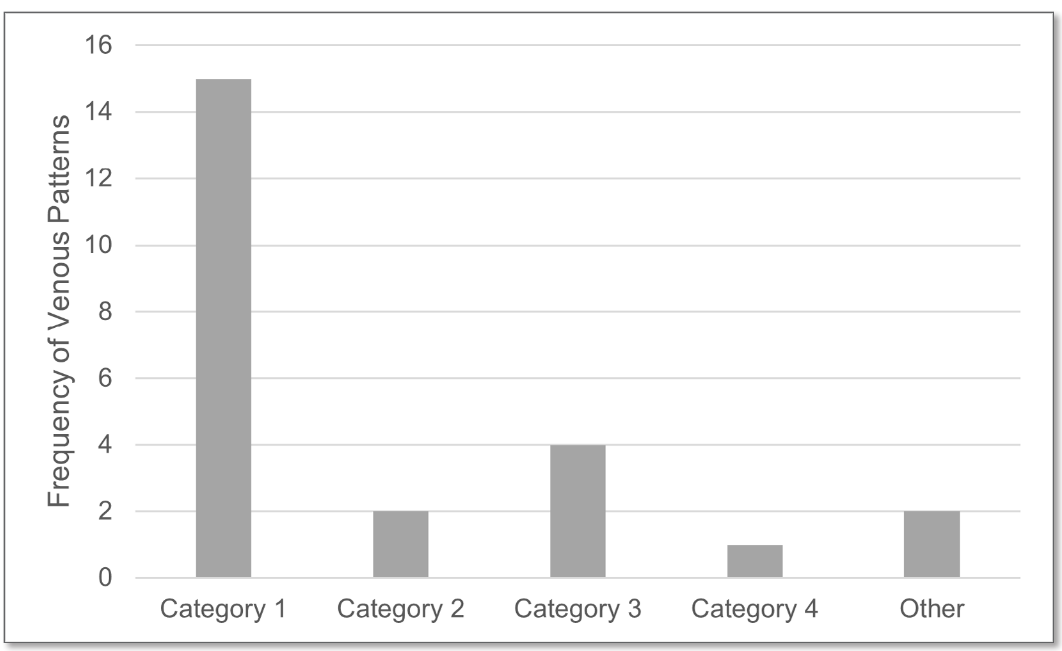

Figure 2. *Frequency of each venous pattern category in dissected cadaveric specimens (n=24).*

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Illustrations of observed cadaveric venous patterns

To allow student review of the venous variations outside of the anatomy lab, we asked a 3D medical artist to create 3D renderings based on our cadaveric observations. These 3D renderings provide directional orientation not easily interpreted on the cadaveric images as we do not photograph the faces of our donors per lab policy. The four frequently encountered superficial venous patterns of the neck that we assigned to categories 1-4 are illustrated in Figure 3. As described previously, category 1 is comprised of the typical union of the ARMV and FV to form the CFV which drains into the IJV (Figure 3A). Category 2 is the union of ARMV and CFV draining into the EJV, compromised of the PRMV + PAV (Figure 3B). Category 3 is an unbifurcated RMV joining the FV to become the EJV (Figure 3C). Category 4 is a more unique variant in which the long CFV runs adjacent to the AJV to drain into the EJV (Figure 3D).

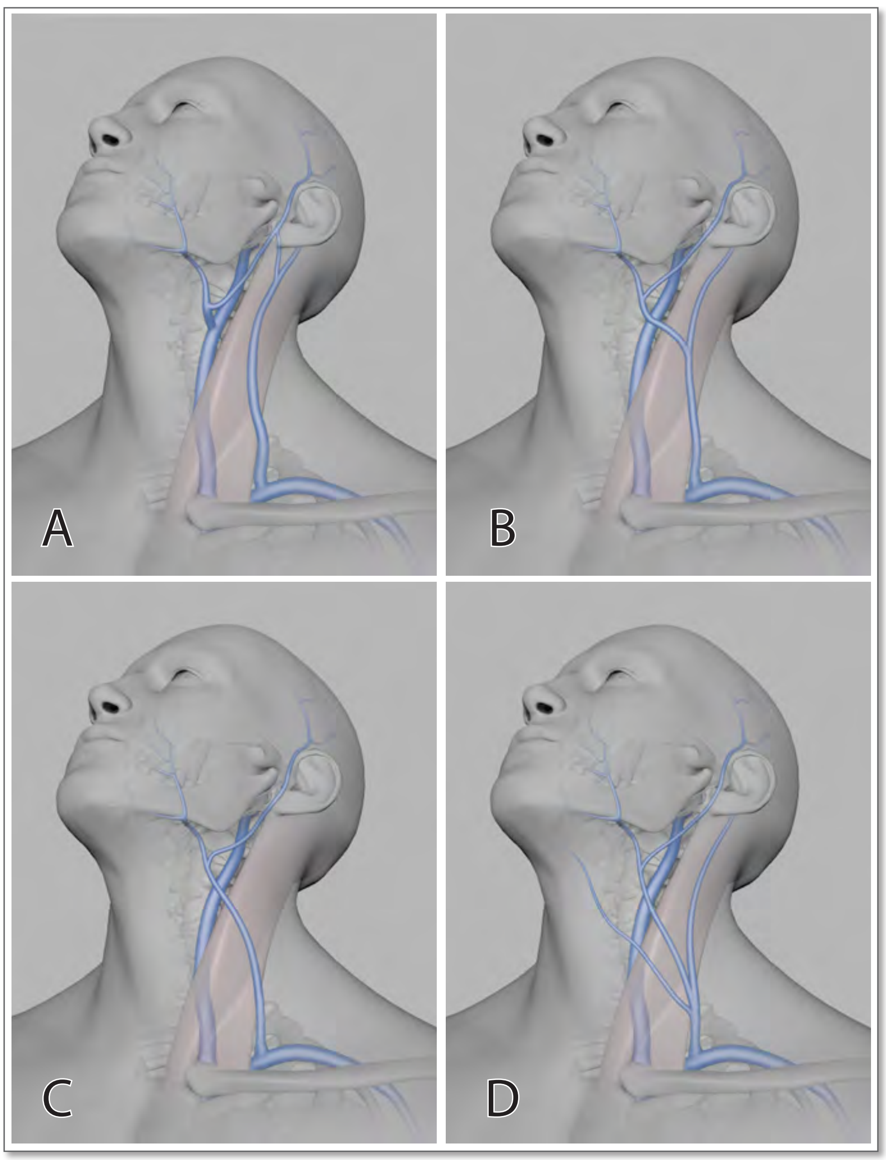

Figure 3. *3D renderings of proposed venous categories, courtesy of Bill Glass, UNMC iEXCEL. A. Category 1: Traditional depiction of FV joining ARMV to form CFV which drains into IJV. B. Category 2: FV joining ARMV to form CFV which drains into EJV. C. Category 3: Undivided RMV joins FV to become EJV. D. Category 4: FV joins ARMV to form lengthy CFV, which alongside AJV drains into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)*

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Visual observations of living subjects' venous patterns

Subjects 1-11, 15, and 19 had visible, identifiable venous structures, whereas subjects 12-14, 16-18, and 20 did not demonstrate identifiable venous structures. Examples of subject photographs demonstrate the visibility of venous structures during maximum effort of Valsalva's maneuver in Figure 4. We worked collectively in a large group (anatomy students and the researchers) to evaluate the images taken of the student volunteers and classified each based on our categories described above. Superficial landmarks were used to do so, and the discussion emphasized the anatomical relationships in superficial and deep planes that would help determine categories (our 3D renderings were particularly helpful here).

The subject in figure 4A has a visible EJV but no tributaries are identifiable. This subject most likely exhibits a Category 1 pattern. The subject in Figure 4B has no visible superficial veins. The subject in Figure 4C has a visible CMV draining into the EJV, which most likely demonstrates the Category 2 pattern. The subject in Figure 4D demonstrates a visible CFV running alongside the AJV, both draining into the root of the EJV, which most likely reflects the Category 4 pattern.

Figure 4: Examples of volunteers performing Valsalva's maneuver to evoke jugular distension. Subject A demonstrates visible EJV, but no tributaries are visible. Subject B does not display prominent superficial veins during Valsalva's maneuver. Subject C displays a visible CFV draining into the EJV. Subject D demonstrates a category 4 arrangement in which FV joins ARMV to form lengthy CFV, which alongside AJV drains into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)

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Discussion

Identification of anatomical variations poses a challenge for anatomy students, yet the frequency with which vascular heterogeneity occurs in the head and neck region warrants recognition. Knowledge of the superficial veins of the neck is important for procedures such as central venous catheterization, myocutaneous flaps, carotid endarterectomies, and central venous pressure monitoring, and the awareness of typical variations is crucial in preventing intraoperative bleeding (Vani et al. 2019). Furthermore, the increasing popularity of minimally invasive aesthetic procedures of the neck, such as botulinum neurotoxin Type A and dermal filler injections, require providers to skillfully avoid such superficial veins in order to reduce associated risks such as ecchymosis and necrosis (Lee et al. 2019).

To date, few studies (excluding isolated case studies) have provided detailed descriptions of observed superficial venous anomalies of the neck (Dalip et al. 2018; Ono et al. 2021; Paraskevas et al. 2014). Our study provided depictions of frequently encountered variations, and describes a reinforcing, simple living anatomy technique that may synergize with cadaveric lab work by anatomy students exploring this territory.

Consistent with what has been reported by others, we observed most frequently the 'textbook' drainage pattern of the FV combining with the ARMV to form the CFV which then drains into the IJV, while the PRMV united with the posterior auricular vein to become the EJV.

Although variations from this pattern have been noted, few studies to date have used a cohort of cadavers to describe more commonly encountered venous variants. Here, we described 4 categories of superficial venous patterns uncovered through cadaveric dissection. While undoubtedly additional patterns exist, our aim was to shed light on the vascular heterogeneity expected in the superficial neck and to emphasize its clinical importance. As stressed by Georgakarakos and Fiska (2022), shedding light on the common anatomical variations future providers will encounter better prepares them for technical success in their treatment/care. By highlighting anomalies, anatomical educators reinforce the need for students to appreciate that no two individuals are identical and critical observation is necessary to anticipate individual variations and associated potential consequences clinically. Additionally, given the use of the CFV as patch material in neck procedures, the heterogeneity of presence and length (8mm to 112mm) of CFVs reported here is an important consideration for providers to be mindful of when treatment planning. Alternatives, including synthetic grafts or alternative autogenous tissue, may be required (Abeysekara et al. 2008).

The Valsalva maneuver is a common method to evoke venous distension for ultrasonic evaluation of the jugular veins. By forcefully exhaling against a closed glottis, the Valsalva maneuver increases intrathoracic pressure and subsequently reduces the preload to the heart, causing the veins of the neck to distend and protrude (Kumar and Van Zundert 2018; Pstras et al. 2016). The pronounced veins are more easily identified and discernable compared to the patient at rest, which allows for the healthcare provider to more easily locate the veins for assessment via ultrasound or for catheterization (Kumar and Van Zundert 2018). Incorporation of Valsalva's maneuver in the anatomical educational setting provides ample opportunity for clinical correlations. We report for the first time its beneficial use in a living anatomy activity focused on identifying superficial veins of the neck.

Despite being a normal activity of daily living (i.e. straining when lifting, during defecation, playing a horn instrument), it is important to avoid unnecessary Valsalva maneuver in high-risk patients (or anatomy students) with conditions including retinopathy, artificial lenses, pre-existing coronary artery disease, valvular disease, or other known congenital abnormalities of the cardiovascular system (Pstras et al. 2016). As an alternative, Lewin et al. (2007) demonstrated humming to be as effective as Valsalva's maneuver at distending the jugular venous system, so this technique may be used as needed. All subjects who participated in our exercise in which the Valsalva maneuver was employed to evoke superficial venous distension were healthy and relatively young in age (~22-38 years of age).

While some of our subjects did not demonstrate discernible venous structures at maximum effort in the Valsalva maneuver, this is to be expected with a variety of factors impacting visibility, including neck size. An extension of this activity could be introduction of vascular ultrasound to observe venous changes during the Valsalva maneuver, as first described by Dr. M. Attubato and colleagues in 1994 (Attubato et al. 1994). While the researchers' compressed anatomy course schedule does not accommodate training in ultrasonography, the integration of point-of-care ultrasound in health professional training is increasing in popularity and may synergize well with this activity. Weiskittel et al. (2021) and Lufler and colleagues (2022) recently shed light on the potential benefits to the incorporation of ultrasound training in the anatomy laboratory which may highlight an opportunity to extend this living anatomy exercise in a clinically relevant way.

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Conclusions

To the authors' knowledge, this is the first description of integrating initial learning of both 'normal' superficial veins of the neck and common variations with a simple living anatomy exercise to bring the anatomy to life. While venous anomalies have been reported in isolated case studies, our investigation of a cohort of cadavers reveals common patterns that may be encountered in both anatomical dissections and living individuals. Despite challenges such as reduced dedicated anatomical course time and financial strain, activities such as the Valsalva maneuver to elucidate venous variations in the neck offer a simple, no-cost means by which students can better engage with the content. Similarly, the opportunity to discuss physiological mechanisms at play during Valsalva's maneuver may encourage integration and knowledge retention. Future studies aimed at understanding the impact of students' exploration of venous variants and living anatomy experience on performance on lab practical exams and/or confidence in translating this awareness to future clinical application may help support its inclusion in the curriculum.

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About the Authors

Rachael K. Krinke, BSc, is a dental student in the class of 2026 at the UNMC College of Dentistry in Lincoln, NE. Shayla D. Yoachim, PhD, is an anatomist and associate professor in the Department of Oral Biology at the UNMC College of Dentistry in Lincoln, NE. She teaches anatomy primarily to dental students and residents and directs the Human Gross Anatomy Laboratory at the UNMC College of Dentistry.

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Back to TOC