The position of the common facial vein in neonates: an alternate route for central venous catheter placement

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Abstract

Introduction: We determine the location of the common facial vein (CFV) in a sample of neonates and assess the safety of this vein as an alternative access route for a central venous catheter (CVC).

Materials and Methods: We dissected both the left and right sides of the neck region of 24 neonatal, formalin-fixed cadavers, exposing the underlying soft tissues and neurovascular structures. We identified the CFV, which we then pinned together with the internal jugular vein, cervical branch of facial nerve, marginal mandibular branch of the facial nerve, the cricoid cartilage, brachiocephalic vein, and the mastoid and sternal attachments of the sternocleidomastoid. We measured the CFV and the related pinned structures.

Results: In neonates, the CFV intersected the anterior border of sternocleidomastoid on average 19.53 mm (left) and 21.73 mm (right) from its sternal attachment.

Conclusion: We found the CFV inferior to the upper one third and just superior to half of the length of the sternocleidomastoid muscle, indicating a possible “safe-zone” where a skin incision could be made over the anteromedial border of sternocleidomastoid. The CFV is easily identified from surrounding landmarks. It could be used as a safe, alternative route for inserting a CVC if its average length (8.72 mm) and diameter (1.50 mm) are taken into account.

Keywords

parenteral nutrition; intravenous, catheter; veins, newborn; neonate, anatomy, surface anatomy, medical education, surgery, vascular access, facial nerve

1. Introduction

Central venous catheters (CVC) are widely used in neonatal intensive care units to provide venous access for multiple reasons, including repeated blood sampling, hemodynamic monitoring, administering vasoactive medication and total parenteral nutrition (Chung and Ziegler, 1998, Costello et al., 2013). Total parenteral nutrition can be provided using various techniques, which can be divided into three main categories: percutaneous catheters (temporary or short-term requirements); tunneled catheters (permanent or long-term requirements) (Chung and Ziegler, 1998); and intraosseous infusion, which involves accessing the bone marrow cavity of long bones when there is no access to the venous system (Boon et al., 2003).

In the past, both percutaneous and tunneled catheters have been successfully inserted via the external jugular vein, internal jugular vein, common facial vein (CFV), the middle thyroid vein, with various guidelines existing for all age groups. An open surgical cut-down (OSC) procedure, which is achieved by ligating the distal end of the exposed vein, is typically done with minimal risk of pneumothorax, hemothorax or pericardial tamponade. The success of OSC is dependent on the caliber of the exposed vein (Chung and Ziegler, 1998, Cruzeiro et al., 2006). Alternatively, peripherally inserted central catheters (PICC) may be used for long-term or permanent total parenteral nutrition. Peripherally inserted central catheters are becoming more popular due to the lower risk of complications or characteristic problems when compared to other tunneled venous catheters. Although PICC is gaining popularity, the vessel walls may be damaged during initial cannulation of the venous structures, and using small-caliber catheters may prevent blood sampling, transfusion and slow fluid rates (< 0.5–1mL/h) may cause blockage (Rocha et al., 2016, Detaille et al., 2010). Peripherally inserted central catheters also most often involve multiple attempts of venous cannulation for successful venous access (Chung and Ziegler, 1998). Tsia *et al.* (2012) admitted 5,502 infants into their neonatal intensive care unit and recorded 362 catheter related sepsis. Of those 362 cases, 234 were PICC related. (Tsai et al., 2012).

Inserting CVCs in neonates is particularly difficult when compared to adults (Chung and Ziegler, 1998, Costello et al., 2013). For neonates, there is more risk of puncturing the carotid artery (Machata et al., 2013) or damaging related nerves (Chung and Ziegler, 1998). Additionally, neonates also have limited venous accessibility, which is the main limitation to providing central venous nutritional support (Chung and Ziegler, 1998). In this paper we explore alternatives to the commonly used external jugular vein (Chung and Ziegler, 1998) and similar locations including the internal jugular vein or subclavian vein.

The CFV is not the preferred primary site for OSC or PICC in neonates, but has been used in the past by Pundez (1966) to treat hydrocephalus via a shunt. By making an incision at the level of the mandible, anterior to the sternocleidomastoid, Pundez (1966) was able to mobilize the CFV to its termination in the internal jugular vein. Zumbro *et al*. (1973) improved on Pundez's technique, using the CFV for an OSC for venous catheter access in neonates. The procedure involved making a short transverse incision over the anterior border of the sternocleidomastoid at the junction of the upper and middle third of the muscle. The CFV is exposed via blunt dissection. Approximately 10 mm from the entrance to the internal jugular vein, an incision is made into the CFV while the vein is controlled distally and proximally. The catheter is then inserted, and the length of the catheter is adjusted until the tip of the catheter is positioned within the superior vena cava near the right atrium of the heart (Zumbro et al., 1973).

The CFV could be used for either primary venous access, or as a secondary option for infants who may require prolonged hospital stay or have had previous CVC insertion failure or where sepsis is likely to occur. Using the CFV as the primary puncture site could benefit neonatal intensive care, especially when the external jugular vein, internal jugular vein or subclavian vein must be spared. In this study, we provide essential anatomical knowledge about the venous system, and related structures that are in danger when a venous catheter (central or peripheral) is inserted in a pediatric patient population. In particular, we determine the position of the CFV and related structures in neonates which need to be considered when placing a CVC.

2. Materials and methods

2.1. Materials

We used a sample of 24 formalin-fixed, neonate cadavers (Ethics clearance: 447/2018). The sample consisted of specimens with extremely low birth weight (<1000g) to low birth weight (1000g ≤ 2500g) (Montes-Tapia et al., 2016). At the time of death, all the cadavers were younger than six weeks. Cadavers were obtained and stored according to the standards set out in the South African National Health Act (61 of 2003). All sample demographics are presented in Table 1. We excluded cadavers with any developmental abnormalities of the neck region or where previous dissections had disrupted the normal anatomy of the region.

Table 1: Demographic information of the neonatal cadavers used to measure the common facial vein (CFV) and related structures

	n	Mean	Std. Deviation
Age at death (days)	24	3.96	8.019
Height (cm)	24	0.35	0.053
Weight (kg)	24	1.10	0.687
BMI	24	8.52	2.446

2.2. Methods

The neonatal cadavers were secured and positioned with the neck slightly extended and rotated contralaterally to the area being dissected. The skin over the anterolateral neck was reflected laterally and carefully loosened from the underlining platysma muscle. The platysma was then cut at the level of the clavicle and reflected superiorly (Figure 1). Care was taken to preserve the cervical and marginal mandibular branches of the facial nerve deep to the platysma. The sternocleidomastoid muscle was exposed and before cleaning and lifting the muscle, the following point was pinned:

- The intersection between the sternocleidomastoid and either the internal jugular vein or CFV.

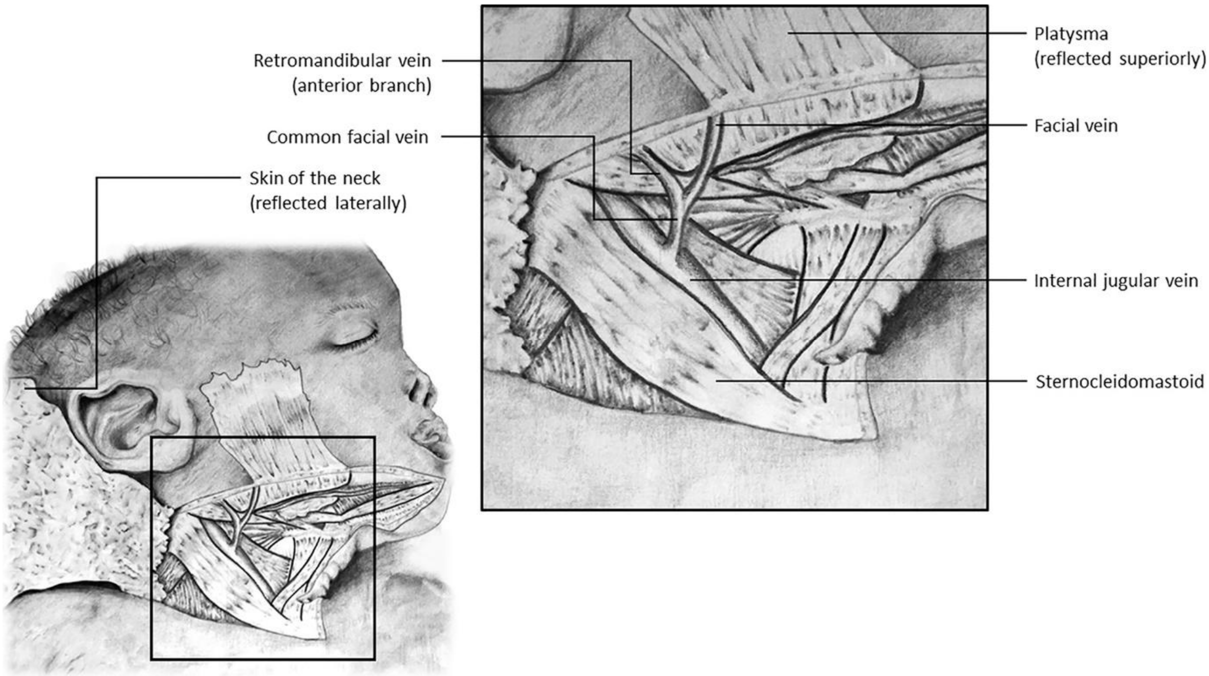

Figure 1: The head is rotated laterally and to a contralateral side to where the measurements were taken. The skin of the neck is reflected laterally and the platysma muscle superiorly. Illustrating the formation of the CFV as the anterior branch of the retromandibular vein joins the facial vein. Additionally, indicate the CFV terminating into the internal jugular vein.

Using blunt dissection, the sternocleidomastoid was cleaned superficially and deep. Following the internal jugular vein superiorly to its various tributaries, the CFV was isolated and cleaned to its origin. Further pins where placed at the following points:

- At the termination of the CFV into the internal jugular vein.
- At the origin of the CFV, where the last tributary of the CFV joins the vein.
- Cervical branch of the facial nerve closest to the origin of the CFV.
- Marginal mandibular branch of the facial nerve closest to the origin of the CFV.
- Mastoid attachment of the sternocleidomastoid.
- Sternal attachment of the sternocleidomastoid.

We used a mechanical dial-sliding caliper with an accuracy of 0.01 mm to measure the following:

1) SCM length: from the mastoid attachment to the sternal attachment of the sternocleidomastoid.

2) M-CFV distance: from the anterior border of the mastoid attachment of sternocleidomastoid to the intersection of the CFV with the anteromedial border of sternocleidomastoid.
3) S-CFV distance: from the medial border of the sternal attachment of sternocleidomastoid to the intersection of the CFV with the anteromedial border of sternocleidomastoid.
4) SCM-IJV distance: from the intersection of the CFV with the anteromedial border of sternocleidomastoid to the termination of CFV into the internal jugular vein.
5) CFV-SCM distance: from the origin of the CFV to the intersection of the CFV with the anteromedial border of sternocleidomastoid.
6) CFV length: from the origin of the CFV to the termination of the CFV into the internal jugular vein.
7) CFV diameter: a small section of the CFV was removed and the diameter of the CFV was measured without any obstructions.

To establish a "safe-zone" or determine the area least likely to cause injury to the branches of the facial nerve, we measured the distance between the marginal mandibular and cervical branches of facial nerve to the origin of the CFV:

8) CFV-CBN the shortest distance between the origin of the CFV and the cervical branch of the facial nerve.
9) CFV-MMN the shortest distance between the origin of the CFV and the marginal mandibular branch of the facial nerve

Additional to determining minimal distances, for each dissection, we observed whether the branches of the facial nerve crossed the origin of the CFV, or the incision site, as proposed by Zumbro *et al*. (1973). We noted the formation of CFV to see if the commonly accepted venous pattern varied. We recorded the relationship between of the origin and termination of the CFV to the cricoid cartilage as being either superior, inferior to the level of the cricoid cartilage.

2.3. Statistical Analysis

Data were summarized using descriptive statistics, including mean, median, standard deviation and 95% confidence intervals. We compared measurements from the left and right sides using a paired t-test or Wilcoxon Signed Rank test, depending on the distribution of the data, after outliers were removed via standardized values. We tested whether measurements were correlated to demographic details (weight, height and BMI) using either a Pearson's correlation or Spearman's rho test. We determined the correlation coefficient or r depending of the linearity of the correlation pair. We calculated regression formulae for correlation pairs that were strongly correlated ($r>0.7$). We used an inter- and intra-observer error analysis to test for repeatability and accuracy, following Bland and Altman (2010) on 25% of the sample ($n = 6$).

3 Results

Most parameters were similar on the left and right sides ($p > 0.05$), except for S-CFV ($p = 0.005$). For all the parameters, except for S-CFV, we combined left and right measurements to form a total sample of n = 46 (Table 2). The average length of sternocleidomastoid was 36.3 ± 5.14 mm. From the sternal attachment, the CFV intersected with sternocleidomastoid on average 19.5 ± 3.39 mm on the left and 21.7 ± 3.82 mm on the right. The distance from the mastoid process to the CFV-SCM intersection averaged 17.0 ± 3.37 mm. The length from the origin of the CFV to the sternocleidomastoid intersection was 8.2 ± 3.73 mm. The length from the sternocleidomastoid intersection to where the CFV terminated in the internal jugular vein was 2.7 ± 0.92 mm.

The cervical branch of facial nerve crossed the origin of the CFV, or the incision site proposed by Zumbro *et al.* (1973), at a mean distance of 0.9 ± 3.21 mm inferior to the origin of the CFV. The marginal mandibular branch of the facial nerve was mostly superior to the origin of the CFV at a mean distance of 5.1 ± 3.49 mm. In two instances, the marginal mandibular branch of the facial nerve crossed the origin of the CFV inferiorly.

Table 2: Descriptive analysis for all measurements of the common facial vein (CFV) in neonates. (n= number of individuals; SD= standard deviation; CI= confidence interval; Min= minimum; Max= maximum; *negative values indicate that the structure was found inferior to the origin of the CFV)

					Mean			95% CI mean	
	n	Range	Min	Max	Statistic	Std. Error	SD	Lower	Upper
SCM length	42	25.42	28.57	53.99	36.33	0.80	5.14	33.63	37.34
M-CFV	41	14.19	11.71	25.90	17.00	0.53	3.37	15.69	18.92
S-CFV (left)	20	13.43	13.12	26.55	19.53	0.76	3.39	17.11	21.91
S-CFV (right)	20	12.50	16.82	29.32	21.73	0.85	3.82	18.51	23.72
SCM-IJV	38	3.34	1.44	4.78	2.69	0.15	0.92	2.01	3.36
CFV-SCM	41	16.12	1.09	17.21	8.15	0.59	3.73	7.03	12.19
CFV length	41	12.41	3.00	15.41	8.72	0.56	3.61	7.39	13.28
CFV diameter	43	1.98	.78	2.76	1.50	0.07	0.49	1.46	2.09
CFV-CBN	32	11.06	-6.60*	4.46	-0.93	0.57	3.21	-3.53*	1.00
CFV-MMN	32	13.02	-1.80*	11.22	5.13	0.62	3.49	1.84	5.44

After reviewing all possible correlation pairs (Table 3), we noted that SCM length was strongly correlated ($r < 0.7$) with S-CFV (left), and that CFV-CBN was strongly correlated ($r < 0.7$) with CFV-MMN. According to Spearman's rho test, the following pairs: CFV-CBN with CFV-SCM; CFV-SCM with CFV length; and S-CFV (left) with S-CFV (right) showed a "good" correlation ($0.5 < r < 0.7$). We generated a regression formula for SCM length and S-CFV (left) (Equation1) (Table 4).

Equation 1: Regression formula for SCM length and S-CFV (left). The "y" represents the length from the sternum to the intersection between the CFV and the sternocleidomastoid. "x" represents the length of the sternocleidomastoid.

$$y = 0.81x - 8.90$$

Table 3: Correlation tests for measurements of the common facial vein (CFV) in neonates.

Correlation pair	n	Pearson's Correlation Coefficient (r)	Spearman's Correlation Coefficient (r)	Sig. (2-tailed)
SCM length and S-CFV (Left)	20	0.813	0.728	0.000
CFV-CBN and CFV-MMN	29	0.781	0.761	0.000
CFV-CBN and CFV-SCM	30	-0.545	-0.581	0.001
CFV-SCM and CFV length	39	0.537	0.515	0.001
S-CFV (left) and S-CFV (right)	18	0.672	0.690	0.002

Table 4: Regression formula for SCM length and S-CFV (left) in neonates

Dependent variable	Model	Std. Coefficients Beta	t	Sig.	R^2 Linear	Std. Error of Estimate
S-CFV (left)	Y-intersect	-8.897	-1.843	0.082	0.660	2.029
	SCM length	0.813	5.915	0.000		

3.1. Qualitative data

In the sample population (Table 5), we noted two variations in the formation of the CFV, which were observed in five neonatal cadavers. We recorded a single case where the CFV did not form, and the retromandibular vein and the facial vein drained directly into the internal jugular vein (Figure 2a). In four neonatal cadavers (8.7%), the CFV drained directly into the brachiocephalic vein instead of the internal jugular vein (Figure 2b). In all the cadavers the CFV originated superior to the cricoid cartilage, and terminated inferior to the cricoid cartilage in 69.2% and superior to the cricoid cartilage in 30.8% of cadavers.

Table 5: Qualitative descriptive data following anatomical investigation of the common facial vein (CFV) in neonates.

		Frequency	Percent	Valid Percent
Cross	No	13	28.3	39.4
	Yes	20	43.5	60.6
	Total	33	71.7	100.0
Pattern	Normal	41	89.1	89.1
	RM-IJV[1]	1	2.2	2.2
	CFV-BCV[2]	4	8.7	8.7
	Total	46	100.0	100.0
O-CC[3]	Superior	39	84.8	100.0
	Total	46	100.0	
T-CC[4]	Superior	12	26.1	30.8
	Inferior	27	58.7	69.2
	Total	39	84.8	100.0

Key:

[1] RM-IJV: Retromandibular vein and the facial vein flows into the internal jugular vein and no CFV was present.

[2] CFV-BCV: The CFV does not flow into the internal jugular vein, however flow directly into the brachiocephalic vein.

[3] O-CC: Origin of the CFV in relation to the cricoid cartilage.

[4] T-CC: Termination of the CFV in relation to the cricoid cartilage.

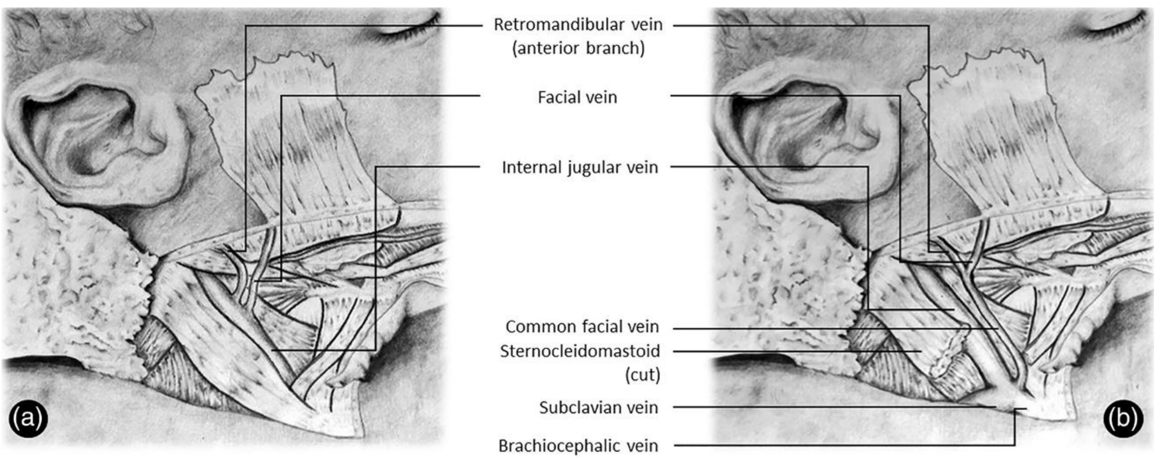

Figure 2: Abnormal variation, (a) Pattern one depicts the facial and retromandibular veins as it drains into the internal jugular vein, and an absent CFV. (b) The second pattern, depict the CFV

being formed by the anterior branch of the retromandibular vein and the facial vein which then directly drains into the brachiocephalic vein.

3.2. Inter-observer and intra-observer error analysis

The inter- and intra-observer error tests showed no differences between the two datasets. Most of the data points fell within the 95% confidence intervals (Bland and Altman 2010). The test did not reveal any biases for the measured variables.

4. Discussion

Our findings support the potential use of the CFV as a safe, suitable alternative site for venous catheterization. In neonates, the CFV is easy to locate with minimal risk to surrounding superficial neurovascular structures. On average the CFV can be found approximately 19.5 mm (left) and 21.7 mm (right) from the sternal attachment of the sternocleidomastoid. Relative to the whole sternocleidomastoid, the CFV can be found just superior to half of the length of the sternocleidomastoid and inferior to the upper two thirds of the length of sternocleidomastoid. Using the regression equation (Equation 1), we can safely and accurately estimate the position of the left CFV in relation to the anterior border of the sternocleidomastoid using the full length of the sternocleidomastoid muscle. Regarding the surrounding structures, only the cervical branch of the facial nerve may be in danger when inserting a venous catheter into the CFV.

Venous catheterization is used in low-and very low birthweight infants to provide total parenteral nutrition for essential fluids and nutrition. These neonates may be unable to feed because they are unconscious, or unable to swallow when enteral feeding is introduced, or have gastric complications such as gastric obstructions or gastroduodenal fistulas, and in some instances, there may be a total non-functioning gastrointestinal tract (Ainsworth and McGuire, 2015). To care for these neonates, it is useful to have multiple options for venous access.

Advances in both medical and surgical care have increased the need for long-term central venous access. Currently, the OSC method is preferred for tunneled central venous access, but percutaneous approaches using ultrasound-guided techniques are becoming more popular (Hong et al., 2013). Percutaneous catheters, which can be inserted at the bedside, are largely used for short-term total parenteral nutrition. Tunneled procedures are preferred for long-term total parenteral nutrition due to reduced rate of complications. With many available options, surgeons will choose a technique and device depending on the size and the condition of the patient. A surgeon will only perform an OSC procedure if the proposed vein is large enough (Chung and Ziegler, 1998, Hong et al., 2013, Montes-Tapia et al., 2016). When OSC is used to insert a venous catheter, the distal end of the vein is ligated and the vein cannot be used again for venous access (Chung and Ziegler, 1998). We identify the CFV as an easy, alternative peripheral puncture site that can be used when the primary venous catheter insertion site becomes infected or irritated. Our findings do not corroborate the position of the CFV or the internal jugular vein as described by Zumbro et al. (1973), who described the intersection of these elements to be at the upper one-third of the sternocleidomastoid. Considering the ratios between mean sternocleidomastoid length and the mean lengths from the sternal attachment and mastoid attachments to the intersection of the CFV or internal jugular vein (Table 2), the CFV can be located just inferior to the upper one-third or just superior to half of the total length of the sternocleidomastoid on both the right and left sides.

Our observations suggest that there are some limitations to using the CFV for primary venous access. The CFV is located close to the branches of the facial nerve, in particular the cervical and marginal mandibular branches. We also noted several variations in the formation of the CFV. Injury to the cervical branch of the facial nerve may cause temporary paralysis of the platysma muscle and should not be a contra-indication for venous access (Daane and Owsley, 2003). We also noted that the cervical branch of the facial nerve ran inferior to the CFV and did not course over the area for access to the CFV. Damage to the marginal mandibular branch of the facial nerve is more of a concern, as it will cause a marked drooping of the ipsilateral lip and chin (Daane and Owsley, 2003). We noted two cases (6.25%) where the marginal mandibular branch was in close proximity to the CFV, and recommend that surgeons should be aware that this branch may be close to the cannulation area. When working with neonates, surgeons should also consider possible variations in venous patterns, which we observed in

11% of the sample (Figure 2a, b). One cadaver did not have a CFV (Figure 2a), which if encountered during CVC, may require ligation of the facial vein or internal jugular vein. Four cadavers had CFVs that terminated in the brachiocephalic vein instead of the internal jugular vein (Figure 2b), which may lead to complications such as phlebitis, and mechanical or chemical irritation of the venous endothelium if tunneling the catheter into the entire length of the CFV and ending directly in the brachiocephalic vein (Rocha et al., 2016, Detaille et al., 2010, Ramasethu, 2008).

To summarize, we can establish a "safe zone" for CVC access by using the origin of the CFV as a reference point, together with the length of the CFV-SCM (8.2 ± 3.37 mm) and the measurements of CFV-MMN and CFV-CBN. In this "safe-zone", a surgeon may make a skin incision without damaging the branches of the facial nerve. The "safe-zone" can be described as being on the anteromedial border of sternocleidomastoid, superior to the superior half of the sternocleidomastoid and inferior to the upper one-thirds of the sternocleidomastoid. An incision of between 7.0 mm and 12.2 mm can be made to expose the CFV, with a confidence level of 95%. Additionally, based on the average length of the CFV (8.7 ± 3.61 mm) and average diameter (1.5 ± 0.49 mm), single lumen pediatric catheters that are 0.9 mm or 1.4 mm wide would be suitable to use in this population.

4.1. Limitations

This study has several limitations. As with any dissection of formalin embalmed cadavers, we encountered tissue stiffness, which complicated the positioning of the cadaver in the correct clinical position. As far as possible, we placed all cadavers in the same position before measuring any parameters. Also, the embalming process may cause soft tissue structures to become obscured before dissection.

5. Conclusion

In this study, we observed that the CFV was located inferior to the upper two thirds and just superior to half of the length of the sternocleidomastoid, providing a possible "safe-zone" for venous access to the CFV. To avoid damage to the facial nerve, we recommend that a skin incision is made over the anteromedial border of sternocleidomastoid. The CFV originates on average 8.2 ± 3.73 mm from the anteromedial border of the sternocleidomastoid. The cervical branch of the facial nerve is on average 0.9 ± 3.21 mm inferior to the origin of the CFV and the marginal mandibular branch of the facial nerve is on average 5.1 ± 3.49 mm superior to the origin of the CFV. Damage to these nerves is less likely when an incision is made over the anteromedial border of sternocleidomastoid. We found two abnormal variations in five cadavers. These variations should be considered when attempting to expose the CFV. Considering the length and diameter of the CFV and with sound knowledge of the anatomy of the area, the CFV can be used as a safe, alternative for CVC insertion in neonates.

Data Availability

The quantitative and qualitative data used to support the findings of this study are included within the article, additional data may be requested from the corresponding author.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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