Available online at www.medicinescience.org

ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2026;15(1):377-83

Challenges and experience factors related to anatomical variations in invasive procedures in the emergency department of a university hospital

Gokhan Taskin, Ramazan Kiyak

Balıkesir University Faculty of Medicine, Department of Emergency Medicine, Balıkesir, Türkiye

Received 20 November 2025; Accepted 17 January 2026
Available online 26 February 2026 with doi: 10.5455/medscience.2025.11.308

Abstract

Anatomical variations may complicate invasive procedures in the emergency department (ED) and reduce procedural success. This study aimed to evaluate the impact of anatomical variations on the success of invasive procedures and to examine the effects of medical staff experience, professional role, and imaging device use. This prospective observational study was conducted between January and September 2025 in the ED of a university hospital. A total of 96 adult patients with identified anatomical variations during invasive procedures were included. Demographic data, procedure type, medical staff characteristics, imaging device use, and procedural outcomes were recorded. Of the patients, 34.4% were female, and the median age was significantly higher in males than in females (p=0.019). A significant positive correlation was observed between years of professional experience and procedural success (r=0.561, p<0.001). Procedural success was significantly higher when anatomical variations were known before the intervention (61.9% vs. 36.0%, p=0.033). Success rates differed significantly according to professional role (p<0.001), with the highest rates observed among paramedics and emergency medical technicians. Although procedures performed with imaging device support showed higher success rates, this difference was not statistically significant (p=0.317). No significant association was found between procedure type and success rate (p=0.659). In ED invasive procedures, medical staff experience and prior awareness of anatomical variations are key determinants of procedural success. These findings are consistent with existing literature emphasizing the importance of experience and anatomical assessment in improving first-attempt success and patient safety in emergency care settings.

Keywords: Anatomical variation, invasive procedure, emergency department, professional experience

Introduction

Emergency departments (ED) routinely perform a wide range of invasive procedures, from airway management and intravenous (IV) access to tube thoracostomy. Successfully executing these procedures is critical; however, complications frequently occur during these procedures due to patient-specific anatomical variations [1,2]. For example, maxillary and laryngeal anatomical variations are a well-known cause of difficult intubation, leading to significantly lower first-attempt success rates than airways with normal anatomy [3]. Similarly, anatomical anomalies in vascular structures or body habitus can complicate procedures such as IV cannulation and central venous catheterization (CVC). Patients with difficult IV access (DIVA) often require ultrasound guidance due to obesity or vascular anomalies, leading to delays in treatment and imaging processes [4,5]. In the ED, invasive procedures are frequently performed under challenging conditions, including time pressure, limited patient cooperation, hemodynamic instability, and incomplete clinical information. These operational challenges are further amplified by patient-specific anatomical variations, which may distort standard anatomical landmarks, limit visualization, or require modification of conventional procedural techniques. Variations in airway anatomy, vascular structures, chest wall configuration, or body habitus may result in failed first attempts, increased complication rates, and escalation to more experienced medical

CITATION
Taskin G, Kiyak R. Challenges and experience factors related to anatomical variations in invasive procedures in the emergency department of a university hospital. Med Science. 2026;15(1):377-83.

Corresponding Author: Ramazan Kiyak, Balıkesir University Faculty of Medicine, Department of Emergency Medicine, Balıkesir, Türkiye
Email: drkiyak3516@gmail.com

DOI: 10.5455/medscience. 2025.11.308

staff or advanced imaging support. Therefore, anatomical variability represents a critical and often underrecognized determinant of procedural difficulty in emergency care settings.

Unexpected anatomical variations causing initial attempts to fail delay emergency intervention and increase the need for transition to a more experienced medical staff or the use of auxiliary techniques [6]. When the initial attempt fails in clinical practice, a more experienced practitioner or an advanced technology device is usually brought in [7,8]. Indeed, clinical data show that the practitioner's experience significantly improves outcomes: In CVC procedures, the success rate of experienced physicians is nearly twice that of their less experienced colleagues, and complication rates are also significantly lower [9]. Advanced tools such as ultrasonography (USG) are effective in overcoming difficulties caused by anatomical variations. One study reported that USG guidance increased the success rate of vascular access in DIVA patients to ~90%, compared to only 25–30% with surface landmarks alone [8,10]. Such adjustments are extremely important because each additional attempt at an invasive procedure carries additional risks. According to a large ED data set, multiple intubation attempts dramatically increase the risk of major complications (hypoxia, bleeding, etc.); this risk increases fourfold on the second attempt and approximately fourteenfold on the fourth attempt [11]. Similarly, repeated vascular access attempts can cause trauma to vascular structures or tissues, while procedural delays due to difficult access can further worsen patient outcomes [4].

Previous studies examining invasive procedures in the ED have largely focused on procedure-specific challenges associated with anatomical variations. In airway management, anatomical difficulties such as limited neck mobility, altered upper airway anatomy, or restricted mouth opening have been associated with failed first-pass intubation, hypoxia, and airway trauma. In vascular access procedures, anatomical variations, including atypical vessel course, deep or nonpalpable veins, and obesity-related landmark distortion, have been linked to multiple insertion attempts, hematoma formation, arterial puncture, and procedural delays. Similarly, in thoracic interventions such as tube thoracostomy, variations in chest wall thickness or rib positioning may increase the risk of incorrect tube placement, bleeding, or inadequate drainage. While these studies provide valuable insights into individual procedures, they remain limited by their narrow procedural focus. In contrast, the present study aims to contribute to the literature by evaluating anatomical variation as a common determinant of procedural difficulty across multiple invasive interventions performed in the emergency department [1,4,8,11].

Despite numerous studies highlighting procedure-specific challenges, knowledge regarding the diversity, frequency, and resulting problems of anatomical variations encountered in EDs remains limited. In other words, while most previous studies have focused solely on the difficulties of a single procedure (such as intubation or CVC placement), clinicians working in the ED are at greater risk of encountering all types of anatomical variations due to the wide range of procedures performed.

The primary objective of this study was to evaluate the impact of anatomical variations on the success of invasive procedures performed in the ED. Secondary objectives included assessing the relationship between procedural success and medical staff experience, professional role, prior knowledge of anatomical variations, and the use of imaging devices.

Material and Methods

Research Model and Ethical Approval

This study was designed as a prospective observational study in the ED of Balıkesir University Hospital. This study used a consecutive sample method, and written informed consent was obtained from all patients or their legally authorized representatives participating in the study. Ethical approval for the study was obtained from the Balıkesir University Health Sciences Non-Interventional Research Ethics Committee on 17/12/2024 with approval number 2024/249.

Research Group

This prospective observational study used a consecutive sampling strategy. All adult patients presenting to the Emergency Department between January 2025 and September 2025 who required an invasive procedure as part of routine clinical care were screened in real time.

Patients were eligible for inclusion if an anatomical variation related to the invasive procedure was identified during pre-procedural assessment or during the procedure itself, and if informed consent for study participation was obtained.

During the study period, 105 patients met the initial screening criteria; 4 patients were excluded due to age <18 years, and 5 patients declined participation. A total of 96 patients aged 18 years or older were included in the final analysis.

Inclusion criteria;

- Age ≥18 years
- Undergoing an invasive procedure in the Emergency Department
- Identification of an anatomical variation affecting the procedure
- Provision of informed consent

Exclusion criteria;

- Age <18 years
- Refusal to participate

No a priori sample size or power calculation was performed, as the study was designed to include all eligible consecutive cases within a predefined study period. This feasibility-based approach is common in prospective observational ED studies and is acknowledged as a methodological limitation.

Clinical Indications for Invasive Procedures

Invasive procedures were performed according to routine ED

DOI: 10.5455/medscience. 2025.11.308

clinical indications determined by the treating medical team. The study protocol did not influence clinical decision-making and only recorded procedures performed as part of standard patient care.

Definition and Identification of Anatomical Variations

An anatomical variation was defined as a patient-specific anatomical feature that deviated from standard anatomical landmarks or expected anatomy and was judged by the medical staff to increase procedural difficulty or require modification of the standard technique. This assessment was performed by the healthcare professional who carried out the procedure, based on bedside clinical evaluation and procedural findings, and, when applicable, supported by imaging guidance such as USG. No standardized anatomical scoring system was applied, as the study was designed to reflect real-world emergency department practice. All findings were recorded immediately after the procedure using a standardized data collection form.

Data Collection

In the study, a standardized data recording form created by the researcher was used to collect demographic data (age, sex), procedural characteristics (type of invasive procedure, success or failure), imaging device use, and medical staff-related variables (professional role and years of experience). Patient identifiers were removed prior to analysis to ensure data confidentiality and privacy. When imaging guidance was required, USG was performed with a portable ultrasound device (Philips Lumify, Philips Healthcare, USA) equipped with a linear transducer suitable for vascular and soft-tissue imaging.

Data Analysis

The normality of continuous variables was examined using the Shapiro-Wilk test. Based on the normality test results, continuous variables in the study were expressed as median (minimum: maximum) and mean ± standard deviation. Continuous variables were compared between study groups using the Mann-Whitney U test. Pearson Chi-Square and Fisher-Freeman-Halton tests were used to compare categorical variables between groups, and categorical variables were given as n and percentage values. If overall significance was obtained after the tests, subgroup analyses were performed using the Dunn-Bonferroni test. Correlation analysis was performed to evaluate the relationship between medical staff experience (years of professional practice, continuous variable) and procedural success (binary outcome: success/failure). Because procedural success was a dichotomous variable, point-biserial correlation analysis was used.

Regression analysis was not performed due to the limited sample size and the presence of multiple procedure types and medical staff roles, which could lead to model overfitting and unstable estimates. Therefore, associations were evaluated using correlation and group comparison analyses appropriate to the distribution and structure of the data.

The analyses of the study were performed using the SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) program, and the type I error rate was accepted as 5% in statistical comparisons.

Result

34% (n=33) of the patients participating in the study were female. The median age of male patients was higher than that of female patients (p=0.019) (Table 1).

Table 1. Age and gender distribution of participants

Variable	Female	Male	p
n (%)	33(34.4%)	63 (65.6%)	
Age (min–max)	47 (22–88)	55 (21–97)	0.019

Procedure success rates differed significantly among professional roles, as demonstrated by chi-square analysis (p<0.001). When success rates were evaluated, it was seen that all procedures performed by the paramedic group were successful (100.0%). The success rate was 88.9% among emergency medicine technicians, 46.4% among nurses, and 27.3% among physicians (Table 2). These differences reflect statistically significant variation in procedural outcomes across medical staff categories.

A moderate positive correlation was observed between medical staff experience (years of professional practice) and procedural success, as assessed by a point-biserial correlation analysis (r=0.561, p<0.001). This finding indicates that increased professional experience is associated with higher procedural success rates (Figure 1).

Table 2. Relationship between the role of the healthcare professional performing the procedure and the procedure success rate

	Role	Physician	Nurse	Emergency Medical Technician	Paramedic	p
		n(%)	n(%)	n(%)	n(%)	
Process Result Successful	**Successful**	15(27.3%)	13(46.4%)	8(88.9%)	4(100.0%)	<0.001
	Failed	40(72.7%)	15(53.6%)	1(11.1%)	0(0.0%)	

Comparison of procedural success across different invasive procedure types revealed no statistically significant difference based on chi-square analysis (p= 0.659). Although success rates varied among procedures, these differences did not reach statistical significance (Table 3).

DOI: 10.5455/medscience. 2025.11.308

Table 3. Relationship between invasive procedure and success rate

Invasive Procedure		IV Access	Arter line	CVC	ETI	Tube Thoracostomy	Foley catheter	Nasogastric tube	p
		n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	
Process Re-sult Successful	Successful	13(54.2%)	6(50.0%)	6(30.0%)	4(28.6%)	3(37.5%)	6(42.9%)	2(50.0%)	0.659
	Failed	11(45.8%)	6(50.0%)	14(70.0%)	10(71.4%)	5(62.5%)	8(57.1%)	2(50.0%)	

IV: intravenous; CVC: central venous catheterization; ETI: endotracheal intubation

Variable	Procedure Success Rate	
	r	p
Age (min–max)	0.561	<0.001

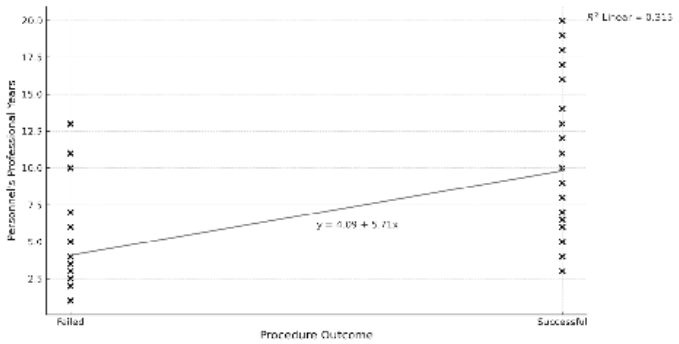

Figure 1. Relationship between the number of years of experience of the healthcare personnel performing the procedure and the procedure success rate

No statistically significant association was found between imaging device use and procedural success according to chi-square analysis (p=0.317). The success rate was 46.8% in procedures using imaging support, while it was 36.7% in procedures performed without the device (Table 4).

Table 4. Relationship between imaging device knowledge and success rate

Variable		Imaging device		p
		Used	Not used	
Process Result	Successful	22(46.8%)	18(36.7%)	0.317
	Failed	25(53.2%)	31 (63.3%)	

Procedural success was significantly higher in cases where anatomical variation was known prior to the intervention compared to cases without such knowledge, as demonstrated by chi-square analysis (p=0.033). The success rate was 61.9% in cases with prior anatomical knowledge versus 36.0% in those without (Table 5).

Table 5. Relationship between imaging device knowledge and success rate

Variable		Anatomical variation information		p
		Yes	Absent	
Procedure Outcome Successful	Successful	13(61.9%)	27(36.0%)	**0.033**
	Failed	8(38.1%)	48(64.0%)	

Years of professional experience were significantly higher among medical staff who achieved successful procedures than among those with failed attempts, based on Mann-Whitney U test results (p<0.001). The professional experience of medical staff in failed procedures was determined to be 4.09 ± 2.86 years, while the professional experience of medical staff in successful procedures was determined to be 8.21 ± 4.65 years (Table 6).

Table 6. Comparison of Years of Professional Experience Between Initial and Subsequent Medical Staff in Failed Procedures

Variables	Staff Professional Years					p
	Average	S.D.	Median	Minimum	Maximum	
Failed	4.09	2.86	3.00	1.00	13.00	0.659
Successful	8.21	4.65	5.00	4.00	17.00	

Discussion

This prospective observational study evaluated the impact of anatomical variations on the success of invasive procedures performed in the ED across multiple intervention types. The main findings indicate that medical staff experience and prior awareness of anatomical variations are significantly associated with higher procedural success, whereas the use of imaging devices was not independently associated with procedural success in this study. By examining a broad range of invasive procedures within a single ED setting, this study contributes to the existing literature by providing a comprehensive, real world assessment of how anatomical variability influences procedural outcomes in emergency care. Notably, even rare patient-specific anatomical anomalies can have important clinical implications for a variety of interventions [12], underscoring the general relevance of anatomical variation to procedural success in acute care.

In this study, anatomical variations were identified by the operating clinician during bedside assessment and/or during the procedure itself, reflecting real-time clinical decision-making in the ED. When used, imaging modalities such as USG supported the identification of atypical anatomy. This personel-based, procedure-specific approach to identifying anatomical variation should be considered when interpreting results, as it differs from the standardized anatomical scoring systems used in procedure-specific studies. Maguire et al.'s study uses formal difficult airway prediction scores [13], whereas our methodology captures

DOI: 10.5455/medscience. 2025.11.308

anatomical challenges as recognized organically in practice.

A key finding of this study was the moderate positive association between years of professional experience and procedural success. This result is consistent with previous research demonstrating that experienced practitioners achieve higher first-attempt success rates and lower complication rates, particularly in technically demanding or anatomically challenging procedures. For instance, a 2025 multicenter analysis reported that emergency physicians had significantly higher first-pass intubation success (80.4% vs 70.9%) and fewer major complications compared to non-emergency specialists [14]. Consistently, a recent review of emergency airway management emphasized that systematic evaluation of potential anatomical difficulties and adequate medical staff training are critical for improving first-attempt success [13]. Innovations in technology can also mitigate the gap in experience: one meta-analysis found that the routine use of video laryngoscopy in the ED significantly increased first-pass intubation success for less experienced medical staff [15]. Taken together, these findings support the notion that accumulated clinical experience enhances the ability to anticipate anatomical difficulties and adapt procedural techniques accordingly, while adjuncts like advanced visualization and simulation-based practice can further improve the proficiency of less seasoned clinicians [16].

Although procedures performed with imaging support demonstrated numerically higher success rates, this difference did not reach statistical significance. This finding may be explained by several factors, including the heterogeneous nature of the procedures included, the limited sample size, and the selective use of imaging in more complex or anatomically challenging cases. Indeed, ultrasound guidance is often employed in the emergency setting for patients with anticipated difficulty, rather than uniformly for all cases, due to practical constraints of time and resources [17]. Therefore, the absence of a statistically significant association should not be interpreted as evidence against the clinical utility of imaging guidance, but rather as a reflection of real-world practice patterns within the study population. In fact, abundant literature demonstrates that imaging guidance can improve procedural success in principle for example, a recent systematic review showed that ultrasound use nearly doubled the first-attempt cannulation success in patients with difficult vascular Access [18]. National guidelines similarly affirm that ultrasound-guided techniques generally increase the success rates of invasive procedures and reduce complication rates [16]. In our cohort, the targeted use of imaging in the toughest cases may have diluted any overall statistical effect, even as imaging likely conferred benefits on a case-by-case basis in those challenging scenarios.

Importantly, prior knowledge of anatomical variations was significantly associated with higher procedural success. This suggests that early recognition of potential anatomical challenges; whether through clinical examination, patient history, or early imaging may be as critical as technical skill alone. Anticipating anatomical difficulty before the first attempt may reduce repeated interventions and improve procedural outcomes in emergency care. This observation aligns with broader evidence that knowing about common anatomic variants can directly contribute to better clinical outcomes [19]. Conversely, unrecognized anatomical variation is a known contributor to procedural failure and complications in many settings [20]. As an illustration, a cadaveric study of airway anatomy found a thyroid ima artery in 14.3% of individuals, an atypical vessel course that could cause unexpected bleeding during cricothyrotomy if not anticipated; the authors emphasized caution and recommended preprocedural ultrasound in non-emergent cases to detect such variants [21]. Prior awareness of patient-specific anatomy; whether through imaging or careful exam thus appears to augment procedural success by allowing the medical staff to tailor technique and prepare for potential difficulties.

The study did not identify significant differences in success rates among different invasive procedure types, indicating that anatomical variation represents a common challenge across procedures rather than being limited to specific interventions. Although multiple invasive procedures were included in the analysis, the present study was not designed to provide detailed, procedure-specific comparative discussions for each intervention type. Procedures such as foley catheterization and nasogastric tube insertion are generally associated with lower technical complexity and complication risk compared to airway, vascular, or thoracic interventions. Therefore, findings related to these procedures were interpreted within the overall framework of anatomical variation and procedural success, rather than through separate, procedure-specific analyses. This approach reflects the primary aim of the study, which was to evaluate anatomical variability as a shared challenge across diverse invasive procedures performed in the ED. This is consistent with reports in the surgical literature that variant anatomy can necessitate technique modifications or lead to complications in virtually any operative field [20]. In other words, whether placing a central line, managing an airway, or performing a surgical drainage, clinicians face a baseline level of anatomical unpredictability that can impact success. Case reports of vascular anomalies exemplify this point: a duplicated inferior vena cava, for instance, may be incidentally discovered and does not itself cause symptoms, yet it can complicate interventional access or lead to misinterpretation of imaging if clinicians are unaware [12]. Our finding that no particular procedure was immune to the effects of anatomical variability reinforces the importance of a universally cautious and adaptive approach. Additionally, medical staff with greater professional experience were more likely to achieve success when procedures were transferred following an initial failure, underscoring the importance of early involvement of experienced personnel in anatomically challenging cases. Current airway management guidelines, for example, advise limiting the number of failed intubation attempts and then escalating to a more experienced provider for subsequent attempts in a difficult airway scenario [22]. In this study, the superior rescue success by more seasoned

practitioners after an initial failure highlights how expert intervention can overcome anatomical hurdles that might thwart less experienced medical staff. Ultimately, these results stress the value of recognizing anatomical variation as a pervasive factor in emergency invasive procedures and of leveraging both clinician experience and supportive technologies or strategies to maximize patient safety and procedural success.

Strengths of the Study

The prospective design and systematic data collection of the study are important strengths. Other notable strengths include the fact that all relevant cases during the study period were recorded using a standardized data form, minimizing observer-related errors. Uniquely, this research examines a wide variety of emergency invasive procedures in a single analysis, providing a comprehensive picture of how anatomical variations affect different procedures, thereby strengthening the study's relevance to clinical practice.

Limitations

This study has several important limitations. First, the sample size was relatively small (96 patients) and was obtained from a single ED; this may limit the generalizability of the findings. Second, patients were enrolled sequentially based on anatomical variation and consent availability, without randomization; therefore, selection biases and unmeasured variables may have influenced the results. In addition, the study included only patients with anatomical variation, and the absence of a comparison group without anatomical variation limits the generalizability of the findings. Although anatomical variation was prospectively recorded, specific subtypes were not systematically categorized, limiting procedure-specific anatomical analyses. In addition, comparisons between professional roles were presented descriptively, as differences in the scope of practice and procedure complexity may confound direct comparisons of procedural success rates.

The study focused on procedural success as the primary outcome; therefore, detailed complication profiles, patient comorbidities, and physiological parameters were not evaluated. Despite these limitations, the prospective design and inclusion of multiple invasive procedures provide valuable insight into real-world ED practice.

Conclusion

In this prospective observational study, anatomical variations and personnel-related factors emerged as important determinants of procedural success during invasive interventions performed in the emergency department. Procedural success was significantly associated with medical staff experience and prior awareness of anatomical variations, whereas imaging device use alone was not independently associated with procedural success in this cohort. These findings highlight that technical skill and anticipatory assessment play a central role in managing anatomically challenging procedures in emergency care.

Beyond reporting procedural outcomes, this study contributes to the existing literature by emphasizing anatomical variability as a common challenge across multiple invasive procedures, rather than a problem confined to specific interventions. The results support a broader, integrative perspective in emergency medicine research that considers anatomical variation, medical staff experience, and real-time clinical judgment as interconnected factors influencing procedural success.

From a practical and academic standpoint, these findings suggest that emergency department practice may benefit from heightened attention to early identification of anatomical difficulty and timely involvement of experienced medical staff when such difficulty is anticipated. Future studies should focus on developing standardized approaches for recognizing anatomical variation in emergency settings and on evaluating structured decision-making pathways that integrate medical staff experience with procedural planning. Such efforts may help improve first-attempt success rates, reduce complications, and enhance patient safety in emergency invasive procedures.

Recommendations

To confirm the accuracy of these findings and increase their generalizability, multicenter cohort studies with larger samples are needed. Future research may include randomized controlled trials comparing traditional methods with advanced techniques such as ultrasound to determine best practices, or designs incorporating educational interventions. Furthermore, collecting data on patient outcomes, such as complication rates and procedure duration, will more clearly reveal the clinical effects of considering anatomical variations.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Ethical approval was obtained from the Balıkesir University Health Sciences Non-Interventional Research Ethics Committee (Decision No: 2024/249; Date: 17 December 2024).

References

1. Nikolla DA, Offenbacher J, Smith SW, et al. First-attempt success between anatomically and physiologically difficult airways in the national emergency airway registry. Anesth Analg. 2024;138:1249-59.
2. Youssef S. Importance of anatomical variations for surgery and clinical practice. WJPLS. 2022;8:157-60.
3. Wang J, Zhao P, Zhou R, et al. Computed tomography–based predictors of difficult intubation in oral and maxillofacial surgery patients. J Oral Maxillofac Surg. 2025;83:937-49. doi:10.1016/j.joms.2025.04.011.
4. Huang D, Winter L, Macauley E, et al. Difficult intravenous access requiring ultrasound in the emergency department: associations with delays in care and areas for quality improvement. Cureus. 2023;15.
5. Juárez-Vela R, Mickiewicz A, Raczyński A, et al. Obesity: a challenge for emergency medical teams-a narrative review. Front Public Health. 2025;13:1659924.

6. Price J, Lachowycz K, Steel A, et al. Intubation success in prehospital emergency anaesthesia: a retrospective observational analysis of the Inter-Changeable Operator Model (ICOM). Scand J Trauma Resusc Emerg Med. 2022;30:44.

7. Struck MF, Fakler JK, Bernhard M, et al. Mechanical complications and outcomes following invasive emergency procedures in severely injured trauma patients. Sci Rep. 2018;8:3976.

8. Maria LT, Alejandro GS, Jesus P-GM. Central venous catheter insertion: review of recent evidence. Best Pract Res Clin Anaesthesiol. 2021;35:135-40.

9. Teja B, Bosch NA, Diep C, et al. Complication rates of central venous catheters: a systematic review and meta-analysis. JAMA Intern Med. 2024;184:474-82.

10. Blanco P. Ultrasound-guided peripheral venous cannulation in critically ill patients: a practical guideline. Ultrasound J. 2019;11:27.

11. April MD, Schauer SG, Nikolla DA, et al. Association between multiple intubation attempts and complications during emergency department airway management: a national emergency airway registry study. Am J Emerg Med. 2024;85:202-7.

12. Awashra A, Shubietah A, Rezkalla A, et al. Duplicated inferior vena cava: a rare anatomical variation. Clin Case Rep. 2025;13:e70411.

13. Maguire S, Schmitt PR, Sternlicht E, Kofron CM. Endotracheal intubation of difficult airways in emergency settings: a guide for innovators. Med Devices (Auckl). 2023;16:183-99. doi:10.2147/MDER.S419715.

14. e Silva LOJ, Von Hellmann R, Besen BAP, et al. Association between physician specialty and first-attempt intubation success in the emergency department. Eur J Emerg Med. 2025;32:430-6.

15. Zhang K, Zhong C, Lou Y, et al. Video laryngoscopy may improve the intubation outcomes in critically ill patients: a systematic review and meta-analysis of randomised controlled trials. Emerg Med J. 2025;42:334-42.

16. Arnold MJ, Jonas CE, Carter RE. Point-of-care ultrasonography. Am Fam Physician. 2020;101:275-85.

17. Çebişli A, Dişel NR, Taşkın Ö, et al. Static ultrasonographic assessment for central venous catheterization reduces catheter dysfunction in the emergency department. J Diagn Med Sonogr. 2024;40:555-61.

18. Anderssen LM, Petersen MS, Wang AG, et al. The efficacy of ultrasound-guided peripheral intravenous cannulation versus the landmark technique in emergency department patients with difficult intravenous access: a systematic review and meta-analysis. J Vasc Access. 2025;Epub ahead of print; doi:10.1177/11297298251347816.

19. Alraddadi A. Literature review of anatomical variations: clinical significance, identification approach, and teaching strategies. Cureus. 2021;13.

20. Kowalczyk KA, Majewski A. Analysis of surgical errors associated with anatomical variations clinically relevant in general surgery: review of the literature. Transl Res Anat. 2021;23:100107.

21. Olson T, Mirjat D, Douglas M, et al. Anatomical variants in the thyroid region and clinical implications for emergency airway procedures: a cadaveric case report. Med Rep. 2024;4:100055.

22. Ahmad I, El-Boghdadly K, Iliff H, et al. Difficult Airway Society 2025 guidelines for management of unanticipated difficult tracheal intubation in adults. Br J Anaesth. 2025;136:283-307. doi:10.1016/j.bja.2025.10.006.