Article

Learning Curve of Landmark-Based TIVAP Placements and Revisions in a Low-Resource Setting

Ann. Ital. Chir., 2026 97, 5: 868–875
https://doi.org/10.62713/aic.4530

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AIM: Totally implantable venous access port (TIVAP) placement is routinely recommended under ultrasound guidance to reduce complications. However, in low-resource settings, the anatomical landmark technique remains widely used. Data evaluating the learning curve of landmark-based TIVAP placement through formal statistical methods are limited.
METHODS: This retrospective single-center study analyzed 1285 consecutive TIVAP-related procedures, including port placement, revision, and removal, performed by a single surgeon between June 2022 and September 2025 using the anatomical landmark technique. The cohort comprised 1093 port catheter placements, 98 removals, and 67 revisions. Technical failure was defined as the inability to achieve venous cannulation or to advance the guidewire/catheter into the central venous circulation and was assessed only in procedures requiring venous access (placements and revisions), in which 27 failures occurred. Cumulative sum (CUSUM) analysis was restricted to procedures requiring venous access to evaluate performance based on technical failure rates; port removals were excluded from the failure-based CUSUM framework. Procedures were additionally stratified by technical complexity. The CUSUM inflection point was used to explore a potential transition in procedural performance.
RESULTS: Technical success was achieved in 1258 of 1285 TIVAP-related procedures (97.9%). A total of 27 cases resulted in technical failure (failure rate: 2.1%), primarily due to unsuccessful venous cannulation or guidewire advancement. CUSUM analysis identified an inflection point at the 422nd case, indicating a transition from the initial learning phase to a phase of performance stabilization. Among procedures requiring venous access, technical failure rates were significantly higher in Phase 1 (cases 1–422) compared with Phase 2 (cases 423–1187) (5.2% vs. 0.7%, $p < 0.001$). Procedural complexity showed only minimal variation across the series, and technical performance remained stable throughout the study period. No further technical failures were observed during the final 252 consecutive procedures. Pneumothorax occurred in 5 cases (0.39% [5/1285] of all procedures; 0.43% [5/1160] of venous access procedures).
CONCLUSIONS: Based on the observed learning curve, procedural stabilization in landmark-based TIVAP placement may require a higher case volume than reported previously for ultrasound-guided approaches. In this single-center, single-operator study, an inflection point at approximately 422 cases was associated with stabilization of procedural performance and a reduction in technical failure rates. These findings suggest that, in low-resource settings where ultrasound guidance is not routinely available, the landmark technique may be performed with an acceptable safety profile under standardized workflows and with adequate training and experience.

Keywords: learning curves; vascular access device; anatomic landmark; central venous catheter placement

Introduction

Totally implantable venous access port (TIVAP) devices are indispensable tools for oncology patients and those requiring long-term parenteral therapy [1]. Current international guidelines recommend performing these procedures under ultrasound (USG) guidance to minimize the risk of complications [2,3]. However, although it has been recognized for more than 35 years that USG guidance improves success rates and reduces complications [4], and despite this well-established body of literature alongside technological advances [5,6], many centers worldwide still rely on the anatomical landmark technique due to resource limitations [7]. In environments where access to technology is limited, the impact of surgical experience and technical proficiency on patient safety becomes much more critical.

The surgical learning curve reflects the process by which a surgeon attains proficiency in a specific procedure and the associated changes in performance over time [8]. Although this curve is traditionally monitored through the decline in complication or technical failure rates relative to the number of cases, total numbers alone can be insufficient for identifying inflection points in a surgeon's individual development. Cumulative sum (CUSUM) analysis is a statistical method that provides an objective and quantitative approach to assessing learning curves and identifying changes in procedural performance over time. While there are nu-

Submitted: 7 January 2026 Revised: 27 February 2026 Accepted: 16 March 2026 Published: 10 May 2026
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Editor: Andrea Zuin

merous studies in the literature regarding port catheter applications performed under USG guidance, data examining high-volume series performed with the landmark technique in technology-limited settings using CUSUM analysis are quite limited.
The primary objective of this study is to evaluate the learning curve of consecutive TIVAP procedures performed by a single surgeon, using CUSUM analysis, with a focus on landmark-based venous access. The study encompasses a comprehensive procedural spectrum, ranging from technically demanding revision cases to standard port placements, within a consecutive clinical workflow. Through this analysis, we aimed to identify the case volume associated with procedural stabilization in the landmark technique and to examine how different levels of surgical complexity influence procedural performance.

Methods

Study Design and Patient Selection

This study was designed as a retrospective analysis of 1285 consecutive TIVAP procedures performed by a single surgeon between June 2022 and September 2025. The case series comprised 1093 port placements, 67 revisions, and 98 port removals. Overall, out of the 1285 procedures performed, 27 resulted in technical failure; these failures are included within the placement and revision categories but are not counted among successful procedures.
All consecutive adult patients (≥18 years) who underwent TIVAP-related procedures for oncological treatment or long-term parenteral nutrition were eligible for inclusion. While patient-level demographic and clinical data were collected, all statistical analyses were performed on a per-procedure basis. All procedures were performed by a single surgeon. Demographic data, procedural details, and outcomes were retrospectively collected from the hospital's electronic medical record system and surgical follow-up documentation. Patients with incomplete medical records were excluded from the study. The patient selection process, procedural pathways, and the scope of procedures included in the CUSUM analysis are summarized in Fig. 1.

Surgical Technique

All procedures were performed in an operating room following standard sterilization protocols. Before the procedure, surface anatomy markings were made to identify the puncture sites, the projected location of the port pocket, and the estimated position of the cavoatrial junction [9]. Based on these markings, the required indwelling catheter length was calculated. Local anesthesia (2% lidocaine) was administered to all patients, supplemented with intravenous sedation when necessary.

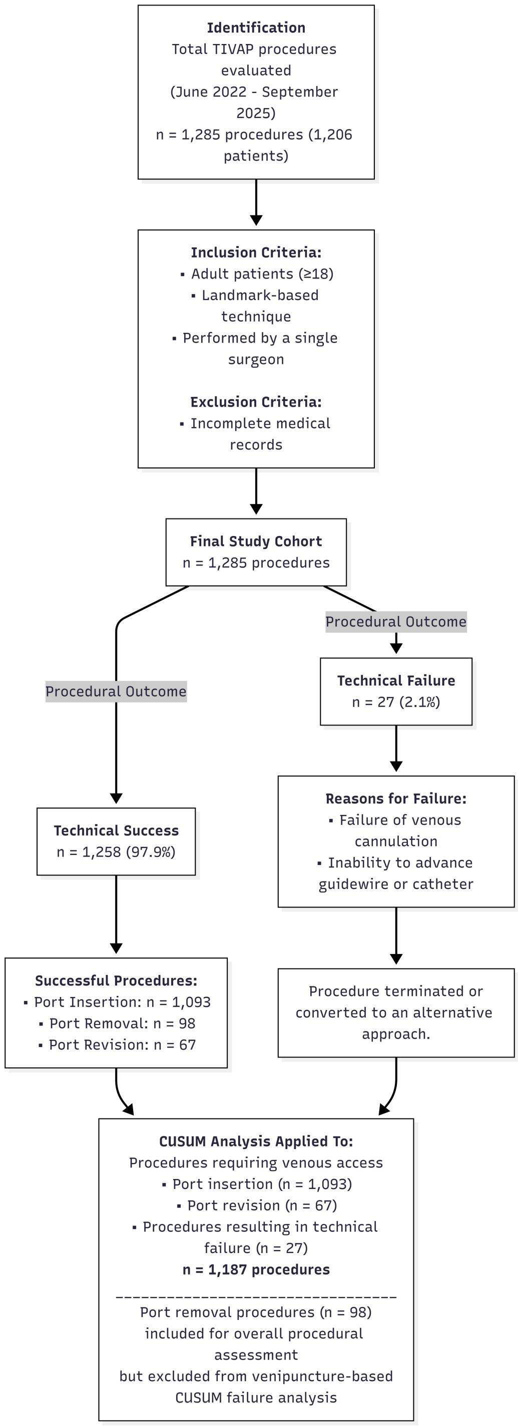

Fig. 1. Flowchart of patient selection, procedural outcomes, and CUSUM analysis eligibility. The flowchart summarizes the selection of TIVAP-related procedures, procedural outcomes, and the subset of procedures included in the CUSUM analysis. CUSUM was applied to procedures requiring venous access, including port placements, port revisions, and procedures resulting in technical failure (n = 1187). Port removal procedures were included for overall procedural assessment but excluded from venipuncture-based CUSUM failure analysis. TIVAP, totally implantable venous access port; CUSUM, cumulative sum.

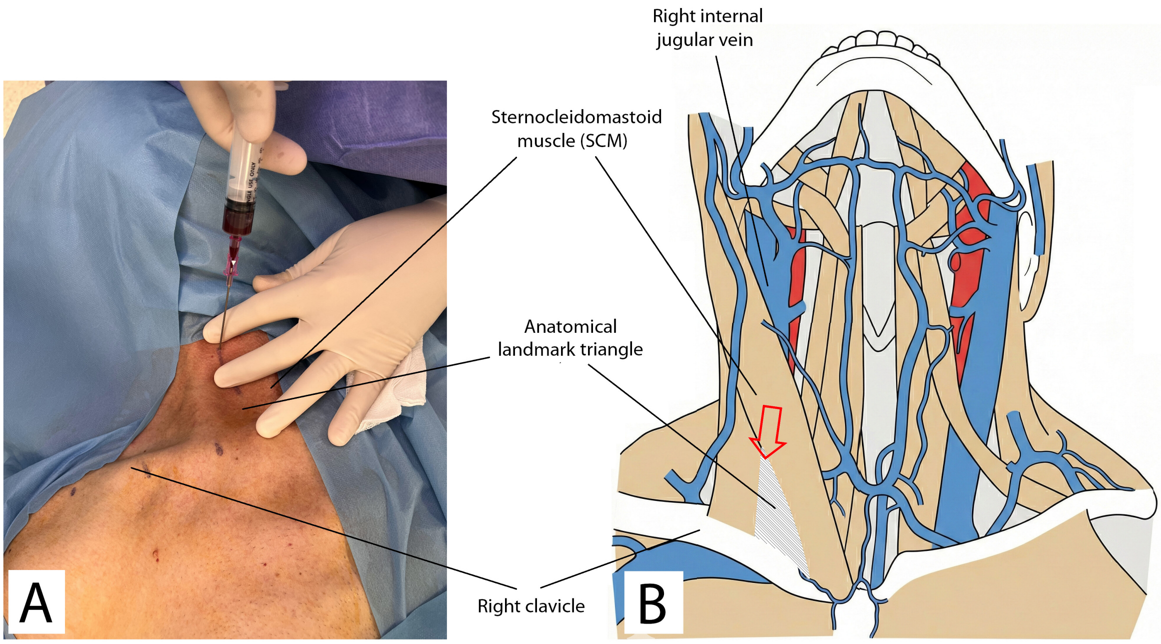

Fig. 2. Landmark-based internal jugular vein puncture. (A) Intraoperative photograph demonstrating the puncture site within the anatomical landmark triangle during right internal jugular vein access. (B) Schematic illustration showing the relevant anatomical landmarks, including the sternocleidomastoid muscle, clavicle and internal jugular vein. The shaded area represents the anatomical landmark triangle, and the arrow indicates the needle trajectory from the skin surface through the subcutaneous tissue toward the internal jugular vein under landmark guidance. Panel B was adapted from Gray H's *Anatomy of the Human Body* (Plate 558; public domain, https://commons.wikimedia.org/wiki/File:Gray558.png), via Wikimedia Commons.

Port Catheter Placement

(a) Positioning and Access:

Patients were positioned in the supine position with the head turned slightly away from the access site and maintained in a mild Trendelenburg position to facilitate venous cannulation. The right internal jugular vein (IJV) was targeted as the primary access route.

(b) Anatomical Landmark Technique:

Instead of ultrasound guidance, the apex of the anatomical triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle (SCM) was designated as the puncture site. Venous cannulation was performed using the Seldinger technique guided by anatomical landmarks. Venous entry was confirmed by blood aspiration, followed by guide wire advancement (Fig. 2). To ensure procedural standardization and safety, pre-procedural mapping was performed by delineating the vein's trajectory and marking the clavicular segments on the skin. Throughout the procedure, the operator maintained continuous anatomical orientation by palpating the SCM muscle and the clavicular head with the non-dominant hand, utilizing tactile feedback for precise needle guidance.

(c) Port Pocket and Tunneling:

A subcutaneous pocket was created over the pectoral fascia below the clavicle. The catheter was passed from the puncture site to the port pocket through a subcutaneous tunnel. The port body was then secured to the fascia. The system was flushed with heparinized saline, and the skin incisions were closed.

(d) Verification:

Optimal placement of the catheter tip was ensured intraoperatively using real-time electrocardiogram (ECG) guidance, specifically monitoring P-wave amplitude changes and the occurrence of arrhythmias to identify the cavoatrial junction [10,11]. Postoperative confirmation was obtained with a posteroanterior chest X-ray in all cases.

Port Catheter Revision

Revision procedures encompassed cases such as catheter malposition, port pocket complications, or catheter dysfunction; these involved either repositioning the port or a complete system replacement, depending on the clinical need.

Port Catheter Removal

Port removal was performed through the existing incision line, dissecting the port body from the surrounding fibrotic capsule, and gently withdrawing the catheter from the vein.

Procedural Complexity Grading

For descriptive purposes, procedures were categorized into three groups based on their technical complexity: port removal was assigned the lowest level (score 1), standard TIVAP placement was assigned moderate complexity (score 2), and revision procedures, being technically the most demanding, were assigned the highest complexity level (score 3). For CUSUM and phase-based analyses, however, only procedures requiring venous access (placements and revisions) were included.

Success and Failure Criteria

'Technical success' was defined as the uncomplicated completion of a functional port system deployment at the targeted anatomical location (cavoatrial junction). 'Technical failure' was defined as the termination of the procedure or the necessity to switch to an alternative surgical method due to the inability to achieve venous cannulation via the anatomical landmark technique or the inability to advance the guide wire/catheter into the central venous circulation. For the purpose of all failure-based and phase-based analyses, procedures requiring venous access were defined as port placements and port revisions (n = 1160), whereas port removals (n = 98) were excluded from these analyses.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software (version 25.0; IBM Corp., Armonk, NY, USA). All continuous variables were found to follow a normal distribution and are expressed as mean ± standard deviation and categorical variables are expressed as frequencies and percentages (%).

The surgical learning curve was evaluated using CUSUM analysis based on technical failure rates. The CUSUM series (S_n) was calculated cumulatively for each case. In this calculation, a value of 1 - p was used for each failed procedure, and a value of -p was used for each successful procedure, where p represents the average failure rate across the entire series. The target value (p) was defined as the overall mean technical failure rate across all venous access procedures.

A positive (upward) slope in the CUSUM plot represents the phase in which the failure rate exceeds the mean and the learning process is ongoing. Conversely, a negative (downward) slope represents a phase of performance stabilization, during which the failure rate declines. The peak of the curve (inflection point) was used to identify the case number at which a change in procedural performance occurred, marking the transition from the initial learning phase to a phase of performance stabilization. No predefined acceptable or unacceptable failure rates or formal decision limits were applied; the inflection point was determined based on the maximum value of the cumulative sum curve within this dataset.

Results

Patient Demographics and Indications

Of the 1285 TIVAP-related procedures included in the study (comprising port placements, revisions, and removals), a total of 1206 individual patients were treated. Among these patients, 725 (60.1%) were male and 481 (39.9%) were female, with a mean age of 60.53 ± 11.61 years.

Table 1. Patient demographics and primary indications for TIVAP placement.

Variable	Value
Age (years), Mean ± SD (patients, n = 1206)	60.53 ± 11.61
Gender (patients, n = 1206), n (%)	
Male	725 (60.1%)
Female	481 (39.9%)
Primary diagnosis (placement procedures, n = 1093), n (%)	
Gastric cancer	287 (26.3%)
Colon cancer	280 (25.6%)
Pancreatic cancer	167 (15.3%)
Rectal cancer	119 (10.9%)
Esophageal cancer	38 (3.5%)
Biliary tract cancer	39 (3.6%)
Breast cancer	40 (3.7%)
Lung and laryngeal cancers	33 (3.0%)
Head and neck cancers	27 (2.5%)
Gynecologic malignancies	25 (2.3%)
Sarcomas	20 (1.8%)
Other malignancies*	18 (1.6%)

*Includes skin (n = 6), male genitourinary (n = 5), hematological (n = 4), and central nervous system malignancies (n = 3). SD, Standard Deviation.

Among the 1093 procedures involving port placement, gastrointestinal malignancies constituted the majority of indications (n = 930, 85.1%), including gastric (n = 287, 26.3%), colon (n = 280, 25.6%), pancreatic (n = 167, 15.3%), rectal (n = 119, 10.9%), biliary tract (n = 39, 3.6%), and esophageal (n = 38, 3.5%) cancers. Non-gastrointestinal indications accounted for 14.9% of cases and included breast cancer (n = 40, 3.7%), lung and laryngeal cancers (n = 33, 3.0%), head and neck cancers (n = 27, 2.5%), gynecologic malignancies (n = 25, 2.3%), sarcomas (n = 20, 1.8%), skin cancers (n = 6, 0.5%), male genitourinary malignancies (n = 5, 0.5%), hematological malignancies (n = 4, 0.4%), and central nervous system tumors (n = 3, 0.3%). The primary indications and detailed demographic data are summarized in Table 1.

Procedural Data and Technical Success

Technical success was achieved in 1258 (97.9%) of the 1285 TIVAP-related procedures. Technical failure occurred in 27 of 1285 surgical procedures (2.1%), primarily due to unsuccessful venous cannulation (n = 16, 59.3%) or failure to advance the guidewire into the central venous system (n = 11, 40.7%). Of the 1258 successful procedures, 1093 were port placements, 67 were port revisions, and 98 were port removals. Among procedures requiring venous access (n = 1160; placements and revisions), the right side was utilized in 1123 cases (96.8%) and the left side in 37 cases (3.2%).

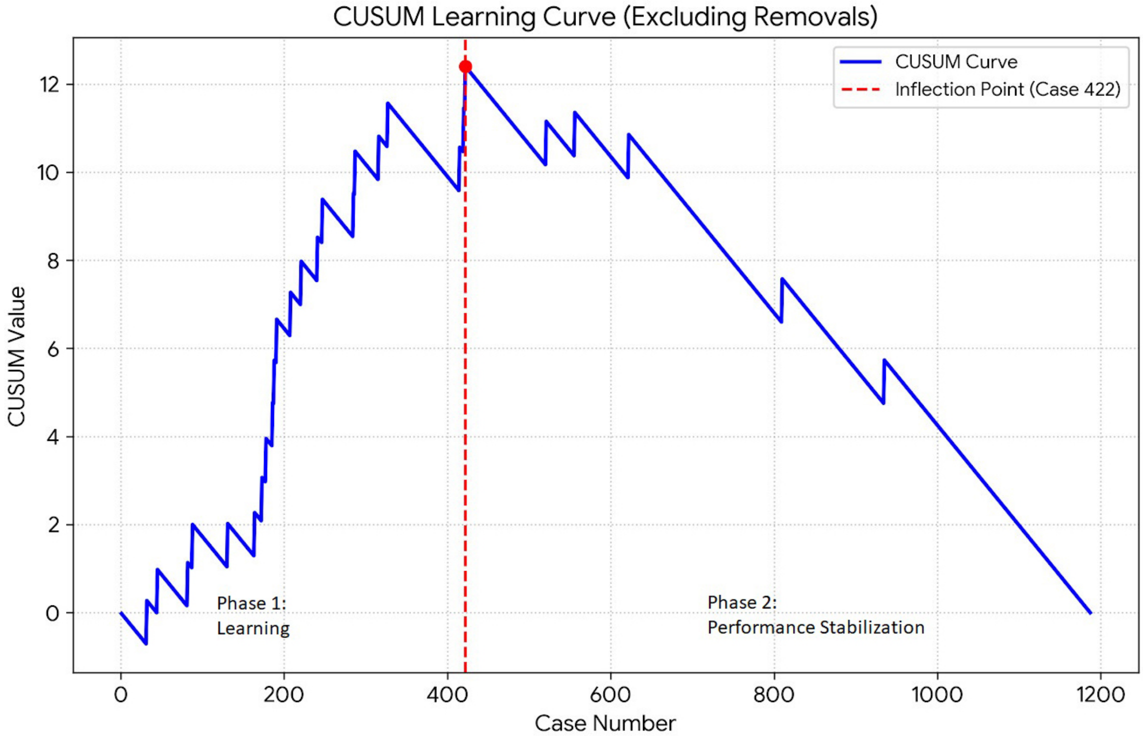

Fig. 3. CUSUM analysis of the surgical learning curve. The cumulative sum analysis (solid blue line) illustrates the performance trend based on technical success and failure during TIVAP procedures (excluding port removals). The vertical red dashed line at the 422nd procedure identifies the peak of the curve (inflection point), marking the transition from the learning phase (Phase 1) to a phase of procedural stabilization (Phase 2).

The internal jugular vein was the preferred access route in 894 cases (77.1%), while the subclavian vein was utilized in 266 cases (22.9%).

Complications and Outcomes

Early procedure-related complications were observed in a very small subset of the cohort. Pneumothorax occurred in 5 cases (0.39% of all procedures [5/1285]; 0.43% of procedures requiring venous access [5/1160]); two of these required chest tube placement, whereas three were managed with conservative follow-up. One case (0.09% of procedures requiring venous access [1/1160]) developed a significant local hematoma that necessitated hospitalization for observation and resolved without surgical intervention. Transient procedural arrhythmias triggered by the catheter tip were promptly corrected by repositioning.

Malposition was identified in 9 cases (0.8% of procedures requiring venous access [9/1160]). The most common pattern was passage from the right subclavian vein to the left subclavian vein (n = 7), followed by passage from the right subclavian vein to the left internal jugular vein (n = 1) and from the right internal jugular vein to the left subclavian vein (n = 1). Regarding late complications, 67 revisions (6.1% of port placement procedures) were performed to manage catheter-related issues such as dysfunction, infection, or thrombosis. No cases of pinch-off syndrome or catheter rupture were observed.

Learning Curve Analysis

The learning curve for TIVAP procedures, evaluated using CUSUM analysis, reached its peak (inflection point) at the 422nd case (Fig. 3). Based on this inflection point, the venous access procedures were divided into two periods: an initial learning phase (Phase 1, cases 1–422) and a subsequent phase of performance stabilization (Phase 2, cases 423–1187). Technical failure rates between the two phases were compared using Fisher's exact test.

The analysis revealed that the majority of technical failures were concentrated in Phase 1, where the cumulative sum of failures exhibited a consistent upward trend. Notably, the moving average of procedural complexity remained stable and consistent as the series advanced into Phase 2. Despite the ongoing inclusion of technically demanding venous access procedures (such as port revisions) in the second phase, the overall failure rate remained significantly lower and demonstrated a stable downward slope on the CUSUM plot. The technical failure rate in Phase 1 was significantly higher than that in Phase 2 ($p < 0.001$), suggesting that procedural performance stabilized after the 422nd procedure. After the last procedural failure occurred at the 935th case, no further technical failures were observed in the subsequent 252 consecutive venous access procedures (238 placements and 14 revisions), indicating a period of sustained procedural stabilization. The mean procedural complexity index differed

Table 2. Comparison of outcomes between Phase 1 and Phase 2 in venous access procedures.

Feature	Phase 1 (n = 422)	Phase 2 (n = 765)	*p*-value
Technical success, n (%)	400 (94.8%)	760 (99.3%)	<0.001
Technical failure, n (%)	22 (5.2%)	5 (0.7%)	<0.001
Complexity index	2.03	2.07	0.002

Phases were defined based on CUSUM analysis of procedures requiring venous access (placements and revisions; n = 1160). Port removals were excluded from phase-based analyses. The complexity index was defined as an ordinal variable (score 2–3), where 2 = standard TIVAP placement and 3 = revision procedures. Group comparisons were performed using a non-parametric method.

statistically between phases (2.03 vs. 2.07, $p = 0.002$), but the magnitude of the difference was small, consistent with a stable case-mix across the series. A detailed comparison of procedural outcomes between the two phases is presented in Table 2.

Discussion

This study presents the procedural outcomes and learning curve of TIVAP-related procedures performed using the anatomical landmark technique in a large consecutive series. A prominent finding is that pneumothorax occurred in 5 cases (0.43% of procedures requiring venous access), despite the absence of ultrasound guidance. In comparison, a recent meta-analysis encompassing 32,665 catheters reported a pooled pneumothorax rate of 1.1%, and an NLP-driven analysis of approximately 18,000 procedures reported a post-insertion pneumothorax incidence of 1.3% [12,13]. Although the pneumothorax rate observed in the present cohort appears lower than those reported in these series, direct comparisons should be interpreted with caution given differences in study design, operator characteristics, case mix, and outcome definitions. The findings of the present study, therefore, suggest an acceptable safety profile within this specific clinical context rather than demonstrating superiority over ultrasound-guided approaches.

Suliman *et al*. [14] emphasized that in resource-limited clinical settings where access to ultrasonography is restricted, the anatomical landmark technique remains vital, and its success is directly contingent upon the practitioner's level of anatomical knowledge. Our study is consistent with this perspective, indicating that anatomical familiarity derived from the thoracic surgery practice may contribute to procedural safety within this specific cohort. The observed pneumothorax rate of 0.43% suggests that, in low-resource settings, the reliability of anatomical landmarks was maintained within this cohort when procedures were performed within a standardized workflow. Furthermore, the inflection point at 422 cases identified through CUSUM analysis was associated with a reduction in technical failure rates over time, rather than establishing a definitive threshold of procedural proficiency.

The learning curves reported for TIVAP placement in the literature are generally shorter than the 422-case threshold identified in our study. This difference may partly reflect methodological and contextual variations across studies rather than a direct discrepancy in procedural performance. First, the rapid stabilization observed in studies such as those by Nguyen *et al*. [15] and Jeon *et al*. [16], typically reported within 15 to 28 cases, should be interpreted in light of ultrasound guidance and differences in operator distribution and case allocation. For instance, Nguyen *et al*. [15] evaluated a total of 150 procedures performed by 30 different physicians, which implies a relatively limited experience per individual practitioner. In such contexts, the detectable inflection point may be influenced by the cumulative case volume per operator and study design characteristics. In contrast, analysis of a large single-surgeon cohort enabled the identification of a statistical inflection point within this dataset, without the volume-related limitations inherent to multi-operator series. Second, there is a notable difference in surgical intensity compared with prior reports. Fosh *et al*. [17] (n = 958), the study most comparable to ours in volume, spanned 16 years with an average of 60 cases per year. Furthermore, that study emphasized the role of technological support (USG and fluoroscopy) in preventing complications and defined a learning threshold of 50 cases. In contrast, our series was completed within approximately three years, with an annual volume approaching 400 procedures. Such procedural density may have influenced the shape and detectability of the learning curve in the present analysis. Despite this high case volume, the CUSUM analysis identified an inflection point at 422 cases, which may reflect differences in analytical approach, outcome definition, and procedural context rather than a direct superiority or inferiority relative to ultrasound-assisted series.

Third, definitions of learning curves are highly heterogeneous across the literature. While many studies focus solely on the reduction of USG-guided venous access [15] or operative time [16], our CUSUM analysis was constructed directly on procedural failure using the landmark technique. Although shortened operative times may indicate surgical familiarity, the 422-case threshold identified in this study represents a statistical inflection point within this specific dataset rather than a universal benchmark of procedural competence. In this context, Yanık *et al*. [18] utilized the landmark technique in 98% of their 3000-case series. Our study represents a consecutive cohort in which this approach was applied exclusively throughout the series. These findings suggest that the landmark technique may be implemented within standardized workflows in resource-limited centers; however, direct comparisons with ultrasound-guided series should be interpreted cautiously given differences in study design and outcome definitions. Beyond operator experience and technique, device-related features have also been shown to influence complication risk in implantable venous access systems, further underscoring that procedural safety is determined by multiple interacting variables [19].

This study has several limitations that should be acknowledged. First, its retrospective design may have imposed constraints on data collection and analysis. Second, all procedures were performed at a single center by a single surgeon, which may limit the direct generalizability of the findings to other institutions, given potential differences including but not limited to operator experience, patient characteristics, institutional workflows, and procedural protocols. In addition, the relatively high annual procedural volume in this single-operator series may have influenced the slope and detectability of the learning curve. Consequently, external generalizability to lower-volume or multi-operator settings should be interpreted with caution. However, for studies specifically focusing on learning curves and procedural safety, this design can also be considered a methodological strength. Operator-related variability in technical preference, sensitivity, and skill level is a well-known confounder in learning curve analyses and may obscure true performance inflection points. While absolute complication rates may differ among surgeons, the observed learning pattern and safety plateau may be informative for experienced practitioners performing landmark-based TIVAP-related procedures in high-volume settings. Third, a direct randomized comparison between the anatomical landmark technique and ultrasound-guided placement was not performed. Finally, as the primary focus of this study was on the learning process and procedural success, very long-term follow-up and late complication data were not included.

Conclusions

In conclusion, the inflection point at the 422nd case identified through CUSUM analysis indicates a transition toward stabilization of procedural performance in landmark-based TIVAP placement. When considered alongside thresholds reported in the literature, this finding may reflect differences in study design, procedural context, and analytical methodology rather than a directly comparable benchmark. This relatively large cohort with high surgical intensity suggests that sustained procedural exposure is associated with a reduction in technical failure rates over time. In centers where access to imaging technologies is limited, the anatomical landmark technique may represent a feasible option when applied within standardized workflows and appropriate clinical oversight. Surgical experience and familiarity with thoracic anatomy may contribute to maintaining low complication rates within such settings.

Availability of Data and Materials

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

OY: Study conception, design, surgical procedures and manuscript writing; MI: Data collection, data analysis and literature review; EE: Data collection and processing; MK: Statistical analysis and interpretation of data; AY: Data collection. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was approved by the Clinical Research Ethics Committee of Basaksehir Çam ve Sakura City Hospital (approval number: KAEK/24.09.2025.292). The requirement for study-specific informed consent was waived due to the retrospective nature of the study. The study conformed to the provisions of the Declaration of Helsinki.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Niederhuber JE, Ensminger W, Gyves JW, Liepman M, Doan K, Cozzi E. Totally implanted venous and arterial access system to replace external catheters in cancer treatment. Surgery. 1982; 92: 706–712.

[2] American Society of Anesthesiologists Task Force on Central Venous Access, Rupp SM, Apfelbaum JL, Blitt C, Caplan RA, Connis RT, *et al*. Practice guidelines for central venous access: a report by the American Society of Anesthesiologists Task Force on Central Venous Access. Anesthesiology. 2012; 116: 539–573. https://doi.org/10.1097/ALN.0b013e31823c9569.

[3] National Institute for Clinical Excellence. Guidance on the use of ultrasound locating devices for placing central venous catheters. Technology Appraisal Guidance No. 49. NICE: London. 2002.

[4] Laméris JS, Post PJ, Zonderland HM, Gerritsen PG, Kappers-Klunne MC, Schütte HE. Percutaneous placement of Hickman catheters: comparison of sonographically guided and blind techniques. AJR. American Journal of Roentgenology. 1990; 155: 1097–1099. https://doi.org/10.2214/ajr.155.5.2120941.

[5] Cajozzo M, Quintini G, Cocchiera G, Greco G, Vaglica R, Pezzano G, *et al*. Comparison of central venous catheterization with and without ultrasound guide. Transfusion and Apheresis Science. 2004; 31: 199–202. https://doi.org/10.1016/j.transci.2004.05.006.

[6] Oulego-Erroz I, González-Cortes R, García-Soler P, Balaguer-Gargallo M, Frías-Pérez M, Mayordomo-Colunga J, *et al*. Ultrasound-guided or landmark techniques for central venous catheter placement in critically ill children. Intensive Care Medicine. 2018; 44: 61–72. https://doi.org/10.1007/s00134-017-4985-8.

[7] Thosani R, Patel J, Gandhi H, Doshi C, Kothari J. Safe and easy method with little modification in technique is useful for successful internal jugular vein cannulation on the same side even after intra-

arterial puncture without using ultrasound guidance in adult cardiac patients. Annals of Cardiac Anaesthesia. 2016; 19: 277–280. https://doi.org/10.4103/0971-9784.179622.

[8] Pusic MV, Boutis K, Hatala R, Cook DA. Learning curves in health professions education. Academic Medicine. 2015; 90: 1034–1042. https://doi.org/10.1097/ACM.0000000000000681.

[9] Hsu JH, Wang SS, Lu DV, Cheng KI, Wang CK, Wu JR. Optimal skin surface landmark for the SVC-RA junction in cancer patients requiring the implantation of permanent central venous catheters. Anaesthesia. 2007; 62: 818–823. https://doi.org/10.1111/j.1365-2044.2007.05139.x.

[10] Ender J, Erdoes G, Krohmer E, Olthoff D, Mukherjee C. Transesophageal echocardiography for verification of the position of the electrocardiographically-placed central venous catheter. Journal of Cardiothoracic and Vascular Anesthesia. 2009; 23: 457–461. https://doi.org/10.1053/j.jvca.2008.12.003.

[11] Gibault P, Desruennes E, Bourgain JL. Peroperative electrocardiographic control of catheter tip position during implantation of femoral venous ports. The Journal of Vascular Access. 2015; 16: 294–298. https://doi.org/10.5301/jva.5000386.

[12] Teja B, Bosch NA, Diep C, Pereira TV, Mauricio P, Sklar MC, *et al*. Complication Rates of Central Venous Catheters: A Systematic Review and Meta-Analysis. JAMA Internal Medicine. 2024; 184: 474–482. https://doi.org/10.1001/jamainternmed.2023.8232.

[13] Breitwieser M, Moore V, Wiesner T, Wichlas F, Deininger C. NLP-Driven Analysis of Pneumothorax Incidence Following Central Venous Catheter Procedures: A Data-Driven Re-Evaluation of Routine Imaging in Value-Based Medicine. Diagnostics. 2024; 14: 2792. https://doi.org/10.3390/diagnostics14242792.

[14] Suliman A, Mohamed A, Saadeldein M. Assessing anatomical knowledge and confidence in central venous catheter insertion: a single-center cross-sectional study among physicians in a resource-limited setting. Annals of Medicine and Surgery (2012). 2025; 87: 1930–1940. https://doi.org/10.1097/MS9.0000000000003169.

[15] Nguyen BV, Prat G, Vincent JL, Nowak E, Bizien N, Tonnelier JM, *et al*. Determination of the learning curve for ultrasound-guided jugular central venous catheter placement. Intensive Care Medicine. 2014; 40: 66–73. https://doi.org/10.1007/s00134-013-3069-7.

[16] Jeon HJ, Ihn K, Ho IG. Learning curve of ultrasound-guided percutaneous central venous port placement in children. BMC Pediatrics. 2024; 24: 507. https://doi.org/10.1186/s12887-024-04990-x.

[17] Fosh B, Canepa M, Eaton M. Long-term venous access insertion: 'the learning curve'. ANZ Journal of Surgery. 2016; 86: 1038–1041. https://doi.org/10.1111/ans.13338.

[18] Yanık F, Karamustafaoğlu YA, Karataş A, Yörük Y. Experience in totally implantable venous port catheter: Analysis of 3,000 patients in 12 years. Turk Gogus Kalp Damar Cerrahisi Dergisi. 2018; 26: 422–428. https://doi.org/10.5606/tgkdc.dergisi.2018.15299.

[19] Yavuz O, Iscan M. Port catheter thickness and its correlation with complications - exploring the millimeter threshold. Journal of Cardiothoracic Surgery. 2025; 21: 60. https://doi.org/10.1186/s13019-025-03817-9.