Pre-operative peripheral intravenous cannula insertion failure at the first attempt in adults: Development of the VENSCORE predictive scale and identification of risk factors

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Article title

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ABSTRACT (275 words)

Study Objective: Our objective was to develop a clinical scale (the VENSCORE) to predict pre-operative peripheral intravenous cannula (PIVC) insertion failure at the first attempt in adults.

Design: This was a prospective multicenter cohort study that included internal validation with bootstrapping.

Setting: The operating rooms of 14 hospitals in southern France from June 2016 to June 2018.

Patients: Consecutive adult patients aged 18 years or older were recruited upon arrival to the operating room, regardless of American Society of Anaesthesiology (ASA) physical status.

Interventions: PIVC insertion on arrival to the OR

Measurements: PIVC insertion failure at the first attempt was the outcome of interest. Data collected included the number of PIVC insertion attempts and potential predictors of the risk of failure (including pre-operative patient characteristics and data relative to the procedure). Uni- and multivariable logistic analyses were performed. Based on these results, the VENSCORE scale was developed to predict the risk of failure of the first PIVC insertion.

Main Results: In total, 3,394 patients were included, and 27 were excluded because of protocol violations. The PIVC insertion failure rate at the first attempt was 20.3%. Based on multivariable analysis, a history of difficult PIVC insertions, high-risk surgery, poor vein visibility, and moderate to poor vein palpability were identified as risk factors for insertion failure at the first attempt. The area under the curve of the predictive model was 0.82 (95% confidence interval: 0.80–0.84). A VENSCORE value of 0 points was associated with a failure rate of 7%, versus 97% for a score of 6.

Conclusions: The four-item VENSCORE scale could be useful for prospectively identifying adults at risk of first PIVC insertion attempt failure.

INTRODUCTION

More than 1.2 billion peripheral intravenous cannulas (PIVCs) were inserted worldwide in 2015 [1], and PIVC insertion is the first invasive procedure performed before the induction of anesthesia in adults. The incidence of failure is estimated to be 17.0–49.1% [2, 3].

Although the first IV cannulation can be easy in most cases in the pre-anesthetic setting because anesthesiologists have a number of potential the target sites, the incidence of failure remains high. First-time PIVC insertion failure has psychological and physical impacts on the patient. It reduces patient confidence in the anesthesia team, induces pain, increases anxiety, and decreases the level of patient satisfaction before anesthesia induction [4]. Fields and colleagues showed that the pain scores of patients were directly associated with the number of punctures [5]. Patients at high risk of intravenous cannulation failure should be simply and quickly identified prior to the first puncture. Unsuccessful PIVC insertions are also stressful for anesthesia providers and a scoring system should alert the clinicians of the need to use additional measures to increase the chances of success (e.g., the use of ultrasound or infrared vein finders) and to avoid an unpleasant patient experience [4, 6-12].

Currently, in adults, the risk of PIVC insertion failure at patient arrival to the operating room is widely evaluated in daily practice by clinician prediction (vein palpability and direct visibility). A scale with objective parameters could enhance subjective clinician prediction to evaluate this risk during the pre-operative anesthesia evaluation. The modified A-DIVA scale was validated in adults in the operating room, emergency department and labor ward [3, 13].

The aim of this prospective multicenter cohort study was to identify predictors of PIVC insertion failure at the first attempt in adults in the operating room applicable at bedside that

can easily be used in clinical practice so as to develop a simplified VENSCORE predictive scale. We hypothesize that a high VENSCORE indicates a high probability of PIVC insertion failure at the first attempt.

MATERIALS AND METHODS

Patients and design

Ethical and scientific approval for this prospective, multicenter cohort study was obtained from the Comité d'Evaluation Ethique de l'Inserm/Institutional Review Board (CEEI/IRB 00003888) of INSERM (5 April 2016, ref 16-295; Chairperson Dosquet), from the Comité Consultatif sur le Traitement de l'Information en matière de Recherche dans le domaine de la Santé (CCTIRS) (12 May 2016, ref 16-283; Chairperson Serre), and from the Commission Nationale Informatique et Libertés (CNIL) prior to the beginning of the study. The study was registered with Clinicaltrials.gov (NCT02789046). Written information on the study was first given and all patients of the 14 participating centers provided oral informed consent prior to inclusion in the study [14]. According to the French law, the CEEI/IRB of INSERM waived the requirement for written informed consent for the 14 participating centers. This manuscript was reported in accordance with TRIPOD (Transparent Reporting of Multivariable Prediction Model for Individual Prognosis or Diagnostic) guidelines [15].

Consecutive adult patients undergoing a surgical procedure in one of the 14 participating hospitals (Centre Hospitalier (CH) Dax, CH Libourne, CH Langon, CH La Réole, CHU Bordeaux, Clinique Ares, Polyclinique Arcachon, CH de Pau, CH Mont de Marsan, CH Tahiti, CH de Saint Denis, Institut Bergonié, Centre d'instruction des Armées Robert Piqué, or CH de Périgueux) between June 2016 and June 2018 were included. The exclusion criteria were previous venous catheter insertion, pregnancy, inhalation anesthesia without PIVC insertion before induction, patient refusal, and inability to provide informed consent.

Outcome

PIVC insertion failure at the first attempt was considered the main outcome variable. PIVC insertion was defined as successful when venous blood reflux was observed via the venous cannula combined with the infusion of ≥ 10 ml of saline serum without resistance or swelling.

Predictors

Based on the clinical observation reported by our anesthesiology staff and pre-existing literature, factors associated with the risk of PIVC insertion failure at the first attempt were identified. These data were collected prospectively and anonymously by the practitioner upon patient arrival to the operating room and included patient history and physical examination results, medical record data, and data pertaining to the patient's condition during PIVC insertion. Practitioners authorized to perform PIVC insertions for the study included certified nurse anesthetists, certified nurses, student nurse anesthetists, anesthesia residents, and board-certified anesthesiologists. The target vein was identified by the anesthesia practitioner before inserting the canula. Outcome variables examined in this study were described in an information form given to all investigators. In detail, the following patient data were recorded:

- Age, height, weight, history of previous difficult PIVC insertions (defined as ≥ 3 attempts) as reported by the patient and anxiety level according to a visual analogue scale (VAS; 0–100) on arrival.
- Sex, American Society of Anesthesiology (ASA) physical status, history of chemotherapy, radiotherapy, intravenous (I.V.) drug use, diabetes, infiltrative pathologies (e.g. mucopolysaccharidosis or scleroderma), burns, cutaneous disorders (e.g., eczematous dermatitis, xerosis, pruritus), connective tissue disorders, intensive care unit (ICU) hospitalizations or any hospital stay exceeding 5 days, arteriovenous fistulas, amputations, or scheduled or emergency surgeries,

and type of surgery (divided into 3 surgery-risk categories for 30-day mortality risk after noncardiac surgery with inclusion of both patients and procedure factors: low-, intermediate-, or high-risk procedures) [16].

- Skin pigmentation (using the Fitzpatrick skin type [17]).
- Vein quality was assessed once for each patient at the site of the first insertion attempt by two independent examiners (i.e., practitioners authorized to perform PIVC insertions for the study in the operating room) for each patient. VAS score (0–100) for vein visibility (with 0 indicating the worst visibility and 100 indicating the best visibility imaginable) and vein palpability (with 0 indicating no palpation possible and 100 indicating the best palpation felt) after tourniquet placement. The vein visibility and palpability scores were categorized as follows: 0–30: poor; 31–70: moderate; or 71–100: good.
- Number of attempts by each practitioner and order of intervention, profession of the first practitioner, years of active practice (categorized as $<$ 5 years or $\geq$ 5 years), lighting conditions (artificial light, oblique light, or daylight), atmosphere/environment (noisy, conflictive, peaceful, silent, or stressful), gloves worn by the practitioner (none, sterile, or single-use), catheter size (the choice of catheter size was left to the practitioner), anatomical location of the insertion site, alternative methods used (e.g., ultrasound or transillumination), difficulty of the technique as evaluated by the practitioner (based on a VAS score of 0–100, where 0 is very easy and 100 is very difficult), and patient VAS pain score during the technique without local anesthesia (0–100, where 0 is no pain and 100 is the worst pain imaginable).

The number of insertion attempts and the choice to wear gloves as recommended were determined at the discretion of the individual operators in each participating center. The type

and size of the catheter and the insertion location for the chosen vein were also decided by each anesthesia provider based on patient comorbidities and the surgery type. Cannula insertion was performed in accordance with current hygiene guidelines [18].

Sample size

According to preliminary data from a previous study conducted in March 2016 at Bordeaux University Hospital on 150 consecutive patients, the PIVC failure rate for the first insertion attempt was 15%. Because a minimum of 10 failed cannulations are required for each predictor in the multivariable logistic model, the minimum number of subjects required for this study, which included 48 variables, was determined to be 3,264, assuming a 2% incomplete questionnaire rate for the main outcome variable.

Statistical analysis

Two patient groups were defined on the basis of success at the first PIVC insertion attempt. The groups were compared using the chi-squared test, Fisher's exact test, or the unpaired sample t-test as appropriate for each variable.

Lighting conditions and atmosphere were used for a better description of the population but were not included in the uni- and multivariable analyses because the reproducibility of the variables was not evaluated. In parallel, parameters related to the cannulation position and the size of the catheter were not included to keep the VENSCORE (VENipuncture SCale in Operating Room Especially) easy to use in practice.

Univariable logistic regression analysis was performed, and odds ratios (ORs) were calculated. Multivariable logistic regression analysis was performed based on the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) guidelines [15]. Variables with a p-value > 0.20 in the univariable analysis or with missing values were not included in the multivariable analysis. A comparison was performed

to verify the absence of a difference in proportion for the main outcome variable between the included events and those with missing data. For the multivariable analysis, variables were then selected via a backward elimination process based on Akaike's information criterion [19].

Adjusted ORs and 95% confidence intervals (CIs) were calculated for selected predictor variables. The 95% CI of the area under the curve of the predictive model was calculated using bootstrapping (1,000 iterations). The model was then adjusted by optimism calculated using bootstrap validation [20]. The 1,000 bootstrapping samples consisted of random samples with replacement. Models were calculated for each sample, and their performances were compared with that of the initial model on the bootstrapping sample and the initial sample. Optimist was defined as the average difference of the performance on the 1,000 samples. Calibration of the model was reported graphically [15]. The predicted risk was divided into tenths; for each tenth, the observation risk and the predicted risk were calculated, and the predicted outcome probabilities (on the x-axis) were plotted against observed outcome frequencies (on the y-axis).

For all variables, a p-value < 0.05 was considered significant. Statistical analysis was performed using R software (Vienna, Austria) [21].

To simplify the application of the model in clinical practice, a score pertaining to the probability of PIVC insertion failure at the first attempt, i.e., the VENSCORE, was derived. For each variable included in the analysis, the points were allocated to the integer portion of the beta coefficient. To obtain the probability of PIVC insertion failure at the first attempt for a given patient, the points for each variable were summed to produce the VENSCORE.

RESULTS

In total, 3,394 patients were enrolled in this study. Twenty-seven patients were excluded because of protocol violations, including inconsistent data (n = 12), use of intraosseous catheters without prior PIVC insertion (n = 12), insertion of an arterial catheter device (n = 1), and PIVC insertion after induction of general anesthesia (n = 2). Data from the remaining 3,367 patients were analyzed. The demographic data are presented in Table 1. Missing data were noted for each variable.

PIVC insertion failure at the first attempt occurred for 684 of 3,367 patients (20.3%) (Table 2). The total numbers of attempts were two for 468 patients (13.9%), three for 138 patients (4.1%), four for 42 patients (1.2%), five for 19 patients (0.6%), and ≥ 6 for 17 patients (0.5%). Overall, 39.9% of patients for whom the first insertion attempt failed had a history of difficult venous access (Table 1).

Data concerning the procedure are presented in Table 2. The PIVC failure rate was 17.4% (n = 258) for the student nurse anesthetists, 21.4% (n = 237) for the certified nurse anesthetists, 23.9% (n = 115) for the certified nurses, 24.8% (n = 30) for the board-certified anesthesiologists, and 25.0% (n = 44) for the anesthesia residents. In the IV insertion failure group, compared with the IV success group, high anxiety (21.8% vs. 15.1%, respectively, $p < 0.01$) and severe pain (16.8% vs. 3.9%, respectively, $p < 0.01$) were more frequent.

Univariable analysis identified 24 variables associated with a failed first insertion attempt (Table 3), including female sex, ASA physical status (I–IV), underweight or obesity, history of difficult PIVC insertions, cutaneous disorders, arteriovenous fistula, infiltrative pathologies, history of chemotherapy and radiotherapy, diabetes, history of burns, high-risk surgery, emergency or 1-day surgery, operator inexperience, Fitzpatrick skin type II or IV, and moderate to poor vein visibility and palpability.

In total, 3156 patients were included in the multivariable analysis (Table 4). The following factors were independently and significantly associated with a failed first insertion attempt: history of difficult PIVC insertions (OR = 8.3 [95% CI: 6.2–11.3]), high-risk surgery (OR = 1.7 [95% CI: 1.3–2.3]), poor vein visibility (VAS score, 0–30; OR = 2.7 [95% CI: 1.7–4.3]), poor vein palpability (VAS score; 0–30; OR = 8.2 [95% CI: 5.2–12.9]) and moderate vein palpability (VAS score; 31–70; OR = 2.4 [95% CI: 1.7–3.4]). The area under the receiver operating characteristic curve of the adjusted predictive model was 0.82 (95% CI: 0.80–0.84), as shown in Figure 1A. The calibration curve is shown in Figure 1B.

The VENSCORE ranged from 0 to 6 and was derived from the beta coefficients of each variable (Table 5). The VENSCORE was calculated only once per patient and was assessed at the site chosen for the first insertion attempt. All variables included in the VENSCORE were scored as 1 or 2 points, and these scores were summed. The VENSCORE represents the likelihood of first PIVC insertion attempt failure, where there is a 7% chance of failure with a VENSCORE of 0, rising to 97% with a VENSCORE of 6.

DISCUSSION

This multicenter prospective cohort study introduces a simple pre-operative scale (VENSCORE) for predicting PIVC insertion failure, which includes four well-known items (history of difficult PIVC insertion, high-risk surgery, visibility of the vein, and palpability of the vein). The scores on this scale, which range from 0 to 6, denote the probability of failure of the first PIVC insertion attempt for a given adult patient. A higher score on the VENSCORE suggests a higher risk of failure for the first attempt of PIVC insertion.

In this study, a history of difficult PIVC insertion was the most significant risk factor for insertion failure, with an OR of 8.3 (95% CI: 6.2–11.3). This item should appear during the pre-operative anesthesiology evaluation. This well-known variable was also a significant predictor of failure in the study of Van Loon and colleagues, which used the A-DIVA scale [3], and that of Civetta and colleagues, which used the EA-DIVA scale [22]. The EA-DIVA score was developed and validated in cases of PIVC insertion failure after three attempts for patients undergoing elective or urgent surgery and not at the first attempt. Vein visibility and palpability are the two main items for clinician prediction, and they are measured by these two scales in adult patients. The area under the curve of the VENSCORE predictive model was lower than the AUCs of A-DIVA and EA-DIVA. This can be explained by the difference in design between the studies. The 4-variable DIVA scale in children is based on clinical observations, including vein visibility and vein palpability associated with age and history of prematurity [23]. In the VENSCORE study, the item “emergency surgery” was not significantly associated with failed cannulation at the first attempt, although the “high-risk surgeries” item did show an association. This result might suggest that patients with multiple comorbidities require more frequent venous punctures, which could reduce the integrity of the

peripheral venous system. The insertion failure rate was higher than that observed in our preliminary study, upon which the sample size required for the present study was calculated. Nevertheless, the insertion failure incidence in this study is consistent with that in the literature, which ranges from 17.0% to 49.1% in the perioperative setting [2, 3].

Many previously described potential risk factors for PIVC insertion failure were not found to be significant predictors of failure in this study, which used the VENSCORE. Obesity and underweight had a significant association with insertion failure in the univariable analysis. In the multivariable analysis, the association was not significant, but the BMI classes were kept in the final model using Akaike's information criterion. The fact that the rounding of the beta coefficient for both BMI classes led to a value smaller than one explains why the BMI classes were not included in the VENSCORE. This result is in contrast to that found in the literature [6, 22, 24-27]. In a study by Juvin and colleagues, only an extremely high body mass index (BMI > 46 kg m^{-2}) was a significant predictor of failure [28]. Intravenous drug use was not a significant predictor of PIVC insertion failure in this analysis even though a 47% failure was observed; in the literature, this relationship has been characterized by equivocal data [3, 22, 24, 25, 29]. However, the lack of significance in our study may be explained by the small number of I.V. drug users included (n = 23). Similarly, a 60% failure of venipuncture was observed in 82 patients with burns. VENSCORE is a scoring system for an entire cohort, but cannot accurately identify predefined high-risk populations. We should keep in mind that these particular patients (obese patient, burned patient, and patient who use I.V. drugs) were associated with a past history of difficult I.V. access. Female sex was associated with insertion failure in two studies [25, 30] but was not a significant predictor in our study according to the multivariable analysis; another study suggested that this association arose from the smaller vein caliber and potentially higher anxiety levels in women [31]. Our results

suggested that the operators spontaneously modified their technique in patients presumed to have difficult venous access according to their clinician prediction. This could also apply to patients who have recently been hospitalized in an ICU or who have sustained burns on the upper limbs. The PIVC insertion failure rates differed significantly according to operator experience (< 5 years or ≥ 5 years of active practice) in univariable analysis. Although seemingly intuitive, this relationship is controversial in the literature.

We chose not to include operator-related variables in the analysis of risk factors for insertion PIVC failure or those related to perioperative atmospheric or lighting conditions; the latter two parameters are difficult to measure objectively and reproducibly. We also decided not to include variables related to the material used during catheterization. We observed that the insertion success rate was higher for larger cannulas, consistent with Lapostolle and colleagues [26]. This may be related to the practitioners' preference for a larger cannula when veins are visible and easily palpated, corresponding to a selection bias.

One obvious limitation of this study was the method of data collection. Patients came from southern France; thus, external validation was not performed in this study. Internal validity is a prerequisite for external validity [32]. Later, an external validation will be performed in new populations from different countries in Europe in an expectation of the wide use of the VENSCORE on patient arrival in operating rooms. The catheters used in this study were mainly 18- and 20-gauge catheters. The choice of catheter size was left to the practitioner. The range of catheter gauge was quite narrow, and thus, our study findings are relevant to smaller gauge catheters. Additionally, because the data were recorded during PIVC placement, the visibility of the veins and palpation quality could have been underestimated in cases of failure. This bias was also reported by Carr and colleagues [29]. After clinical

examination, the order of intervention between practitioners and the profession of the first practitioner were not defined. Because clinical prediction is an unconscious reflex in practitioner daily practice, our results are probably associated with a selection bias: the more difficult patients were likely assigned to more specialized practitioners. The sample size was calculated according to a single center where practitioners' prior experiences would differ, which is a limitation of the study. However, these centers shared some characteristics: they used mainly 18- and 20-gauge catheters and the more difficult patients were being assigned to more specialized practitioners. The incidence of past difficult venous access may also have been overestimated in this study. Patients with a prior history of painful PIVC insertion may have mistakenly interpreted the event to result from the difficulty of the technique. This recall bias has been described in many studies [7, 31]. Overall, a prediction model should be a simple clinical scale, with objective parameters well known by clinicians. This scale could be used for the early recognition of patients at high risk for difficult intravenous access to improve their comfort and decrease the incidence of severe pain during PIVC insertion. In the VENSCORE study, 61.5% of the patients who experienced first PIVC insertion attempt failure reported moderate to severe pain. Pain is associated with dissatisfaction. We did not assess patient satisfaction or certain confounding predictors of venipuncture difficulty, which is a limitation for this study. For patients with a high probability of difficult PIVC insertion, alternative techniques and newer technologies (e.g., ultrasound or infrared vein finders) should be considered first. Ultrasound guidance has been demonstrated to improve the insertion success rate, shorten the overall procedural time, and limit the number of insertion attempts, especially when difficult access for PIVC insertion is anticipated in adults [2, 4, 6-10]. The VENSCORE could help practitioners identify patients with a high risk of PIVC insertion failure at the first attempt and to anticipate the choice of ultrasound-guided puncture. Increasing interest in point-of care ultrasound for anesthetics is associated with ultrasound

guidance in routine practice for procedures, which could include PIVC insertion at the first attempt [33]. Further studies are needed to determine whether the use of alternative techniques in patients with a high VENSCORE value increases the success rate of the first attempt.

CONCLUSION

The VENSCORE scale, which includes four items, is a reliable assessment instrument useful for identifying patients with a high risk of PIVC insertion failure at the first attempt on arrival at the operating room. Further studies are needed to determine how the VENSCORE scale could be integrated into perioperative protocols to reduce failure rates and improve patient comfort.

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1 Assistance with the study

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3. Presentation

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EA: a) participating in the design, execution, analysis, and interpretation of the work, b) drafting the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including

accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

FR: a) participating in the execution, analysis, and interpretation of the work b) drafting the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

BM: a) participating in the analysis and interpretation of the work, b) drafting the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

MR: a) participating in the analysis and interpretation of the work, b) drafting the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

MS: a) participating in the design, execution, analysis of the work b) revising the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

AO: a) participating in the execution and interpretation of the work, b) revising the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

MB: a) participating in the execution and interpretation of the work, b) revising the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

SR: a) participating in the design, execution, analysis of the work b) revising the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

FSG: a) participating in the design, execution, analysis, and interpretation of the work, b) revising the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

KNG: a) participating in the design, execution, analysis, and interpretation of the work, b) drafting the manuscript critically for important intellectual content, c) giving final approval of the version to be published, and d) taking accountability for all aspects of the work, including

accuracy and validity of the contents, and ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

LEGEND FIGURE

Fig. 1: 1A. Receiver operating characteristics (ROC) curves for the adjusted predictive model. The x-axis is the false positive rate, the y–axis on the left is the true positive rate and the y-axis on the right with color corresponds to the threshold distinguishing between the success and failure of the PIVC insertion**.**

1B Calibration curve. The predicted risk was divided by tenths, for each tenths the observation risk and the predicted risk was calculated. For each tenth represented by a red circle, predicted outcome probabilities (on the x-axis) were plotted against observed outcome frequencies (on the y-axis).

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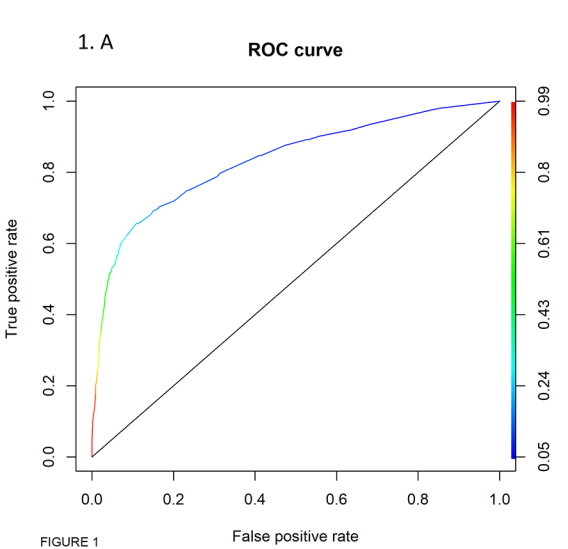
1. A
ROC curve
True positive rate
False positive rate
0.0
0.2
0.4
0.6
0.8
1.0
0.99
0.8
0.61
0.43
0.24
0.05

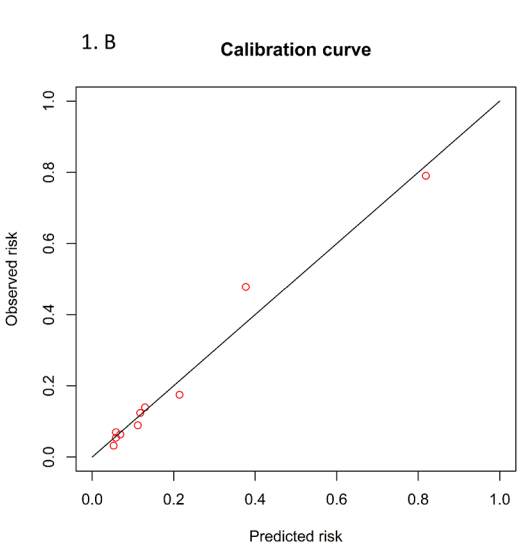
1. B
Calibration curve
Observed risk
Predicted risk
0.0
0.2
0.4
0.6
0.8
1.0

FIGURE 1

TABLE 1. Preoperative patient characteristics

	PIVC insertion Success at the first attempt (n=*2683*)	PIVC insertion Failure at the first attempt (n=*684*)	P
Age (years), mean (SD)	54.2 (18.0)	55.3 (17.9)	0.17
Missing, n (%)	0 (0)	0 (0)	
Sex			**<0.01**
Male, n(%)	1291 (48.1)	298 (43.6)	
Female, n (%)	1362 (50.8)	375 (54.8)	
Missing, n (%)	30 (1.1)	11 (1.6)	
ASA Physical Status			**<0.01**
I, n (%)	729 (27.2)	112 (16.4)	
II, n (%)	1350 (50.3)	306 (44.7)	
III, n (%)	557 (20.8)	249 (36.4)	
IV, n (%)	16 (0.6)	7 (1.0)	
Missing, n (%)	31 (1.2)	10 (1.5)	
BMI (kg m^{-2}), mean (SD)	26.4 (6.0)	25.7 (5.2)	**<0.01**
Missing, n (%)	28 (1.0)	7 (1.0)	
Ambulatory surgery (yes), n (%)	1003 (37.4)	193 (28.2)	**<0.01**
Missing, n (%)	8 (0.3)	0 (0)	
Context of surgery n (%)			**0.04**
Scheduled surgery	2592 (96.6)	648 (94.7)	
Emergency surgery	90 (3.4)	35 (5.1)	
Missing	1 (0.0)	1 (1.5)	
Surgical risk category[13] n (%)			**<0.01**
Low †	625 (23.3)	140 (20.5)	
Intermediate ††	1449 (54.0)	279 (40.8)	
High †††	545 (20.3)	246 (36.0)	
Missing	64 (2.4)	19 (2.8)	
History of			
Difficult I.V. access, n (%)	98 (3.7)	273 (39.9)	**<0.01**
Radiotherapy, n (%)	119 (4.4)	34 (5.0)	0.62
Chemotherapy, n (%)	198 (7.4)	76 (11.1)	**<0.01**
Diabetes, n (%)	181 (6.7)	64 (9.4)	**0.02**
Hospital stay exceeding 5 days, n (%)	187 (7.0)	45 (6.6)	0.78
Intensive Care stay, n (%)	36 (1.3)	10 (1.5)	0.95
I.V. drug abuse, n (%)	16 (0.6)	7 (1.0)	0.34
Burn, n (%)	7 (0.3)	6 (0.9)	0.05
Cutaneous Disorders, n (%)	33 (1.2)	49 (7.2)	**<0.01**
Connective tissue disorder, n (%)	6 (0.2)	16 (2.3)	**<0.01**
Arteriovenous fistula, n (%)	22 (0.8)	28 (3.8)	**<0.01**
Amputation, n (%)	9 (0.3)	4 (0.6)	0.55
Fitzpatrick skin type[14] n (%)			**0.02**
I	764 (28.5)	164 (24.0)	
II	1431 (53.3)	383 (56.0)	

III	326 (12.2)	90 (13.2)
IV	122 (4.5)	29 (4.2)
V	21 (0.8)	7 (1.0)
VI	15 (0.6)	11 (1.6)
Missing	4 (0.1)	0 (0.0)

ASA: American Society of Anesthesia Physical Status, BMI: body mass index, calculated as weight in kilograms divided by height in square meters, PIVC: peripheral intravenous cannula, IV: intra venous,

† Superficial surgery, breast, dental, endocrine thyroid, eye, reconstructive, Carotid asymptomatic (CEA or CAS), gynaecology minor, orthopaedic minor (meniscectomy), urological minor (transurethral resection of the prostate)

†† intraperitoneal (splenectomy, hiatal hernia repair, cholecystectomy), carotid symptomatic (CEA or CAS), peripheral arterial angioplasty, endovascular aneurysm repair, head and neck surgery, neurological or orthopaedic major (hip and spine surgery), urological or gynaecological, renal transplant, intra thoracic non major

††† aortic and major vascular surgery, open lower limb revascularization or amputation or thromboembolectomy, duodeno-pancreatic surgery, liver resection, bile duct surgery, oesophagectomy, repair of performed bowel, adrenal resection, total cystectomy, pneumonectomy, pulmonary or liver transplant

Values are represented as mean (SD) or numbers (percentage). Patients are compared with the Chi-squared test, the Fisher's exact test and the unpaired sample T-test as appropriate.

Bold values represent $P < 0.05$

TABLE 2. Procedure related characteristics

	PIVC insertion Success (n=*2683*)	**PIVC insertion Failure (n=*684*)**	**P**
Operator's experience[†]			**0.04**
≥ 5 years, n(%)	1083 (40.4)	301 (44.0)	
< 5 years, n(%)	1574 (58.7)	367 (53.7)	
Missing, n(%)	26 (0.9)	16 (2.3)	
Wearing gloves[†]			
No, n(%)	719 (26.8)	155 (22.7)	**0.03**
Sterile gloves, n(%)	30 (1.1)	4 (0.6)	0.34
No sterile gloves, n(%)	1926 (71.8)	518 (75.7)	**0.04**
Missing, n(%)	8 (0.3)	3 (0.4)	
Cannulation place[†]			**<0.01**
Hand, n(%)	1583 (59.0)	338 (49.4)	
Forearm, n(%)	678 (25.3)	173 (25.3)	
Antecubital, n(%)	377 (14.1)	141 (20.6)	
Upper arm, n(%)	16 (0.6)	12 (1.8)	
Others, n(%)	6 (0.2)	6 (0.9)	
Missing, n(%)	24 (0.9)	14 (2.0)	
Cannulation side[†]			
Right, n(%)	1038 (38.7)	256 (37.4)	0.59
Left, n(%)	1469 (54.8)	360 (52.6)	0.34
Missing, n(%)	176 (6.6)	69 (10.1)	
Size of the applied catheter[†]			**<0.01**
14 gauge, n(%)	2 (0.1)	0 (0.0)	
16 gauge, n(%)	59 (2.2)	12 (1.8)	
18 gauge, n(%)	1364 (50.8)	276 (40.4)	
20 gauge, n(%)	1172 (43.7)	342 (50.0)	
22 gauge, n(%)	33 (1.2)	27 (3.9)	
24 gauge, n(%)	0 (0.0)	4 (0.6)	
Missing, n(%)	53 (2.0)	23 (3.4)	
Visual appearance score			**<0.01**
Poor: 0 to 30, n(%)	120 (4.5)	249 (36.4)	
Moderate: 31 to 70, n(%)	1036 (38.6)	272 (39.8)	
Good: 71 to 100, n(%)	1527 (56.9)	162 (23.7)	
Missing, n(%)	0 (0.0)	1 (0.1)	
Palpable appearance score			**<0.01**
Poor: 0 to 30, n(%)	103 (3.8)	264 (38.6)	
Moderate: 31 to 70, n(%)	953 (35.5)	272 (39.8)	
Good: 71 to 100, n(%)	1627 (60.6)	148 (21.6)	
Missing, n(%)	0 (0.0)	0 (0.0)	
Anxiety scale Level[†]			**<0.01**
Low: 0 to 30, n(%)	1123 (41.9)	248 (36.3)	
Moderate: 31 to 70, n(%)	1151 (42.9)	285 (41.7)	
High: 71 to 100, n(%)	405 (15.1)	149 (21.8)	
Missing	4 (0.1)	2 (0.2)	

Pain score†			**<0.01**
0 to 30, n(%)	1741 (64.9)	261 (38.2)	
31 to 70, n(%)	708 (26.4)	306 (44.7)	
71 to 100, n(%)	104 (3.9)	115 (16.8)	
Missing, n(%)	1 (0.0)	2 (0.3)	
Lighting conditions†			**<0.01**
Artificial light, n(%)	2022 (75.4)	552 (80.7)	
Oblique light, n(%)	227 (8.5)	46 (6.7)	
Daylight, n(%)	396 (10.7)	76 (11.1)	
Missing, n(%)	38 (5.4)	10 (1.5)	
Atmosphere†			**<0.01**
Noisy, n(%)	457 (17.0)	101 (14.8)	
Conflictive, n(%)	7 (0.2)	2 (0.3)	
Peaceful, n(%)	2037 (75.9)	539 (78.8)	
Silent, n(%)	115 (4.3)	17 (2.4)	
Stressful, n(%)	31 (1.2)	17 (2.4)	
Missing, n(%)	36 (1.3)	8 (1.3)	
Cannulation difficulty score†			**<0.01**
0 to 30, n(%)	1871 (69.7)	117 (17.1)	
31 to 70, n(%)	708 (26.4)	320 (46.8)	
71 to 100, n(%)	104 (3.9)	246 (36.0)	
Missing, n(%)	1 (0.0)	1 (0.1)	

Values are represented as numbers (percentage). Patients are compared with the Chi-squared test, Fisher's exact test and the unpaired sample T-test as appropriate.
† Excluded because of inadequate reproducibility or absence of clinical relevance
Bold values represent $P < 0.05$

TABLE 3. Univariate Logistic Regression Analysis, Identifying Potential Risk Factors Which are Associated With a Failed First Attempt of Peripheral Intravenous Cannulation insertion

	Estimate	Standard Error	P value	Odds Ratio	95% IC
Age	0.003	0.003	0.18	1.00	1.00-1.01
Sex	0.176	0.087	**0.04**	1.19	1.01-1.42
ASA Physical Status†					
II	0.389	0.120	**<0.01**	1.48	1.17-1.87
III	1.068	0.127	**<0.01**	2.91	2.27-3.74
IV	1.046	0.464	**0.02**	2.85	1.07-6.83
BMI					
< 20 kg m^{-2}	0.518	0.212	**0.01**	1.68	1.10-2.52
> 25 kg m^{-2}	0.224	0.089	**0.01**	1.25	1.05-1.49
Emergency surgery	0.442	0.204	**0.03**	1.56	1.03-2.30
History of					
Difficult PIVC insertion	2.865	0.129	**<0.01**	17.56	13.68-22.70
Radiotherapy	0.120	0.199	**<0.01**	1.13	0.75-1.65
Chemotherapy	0.450	0.142	**<0.01**	1.57	1.18-2.06
Diabetes	0.356	0.152	**0.02**	1.43	1.05-1.91
Hospital stay exceeding	-0.062	0.172	0.72	0.94	0.66-1.30
5 days	0.087	0.360	0.81	1.09	0.51-2.13
Intensive Care stay	0.544	0.455	0.23	1.72	0.66-4.05
I.V. drug abuse	1.219	0.558	**0.03**	3.38	1.09-10.22
Burn	1.824	0.229	**<0.01**	6.20	3.97-9.79
Cutaneous Disorders	2.369	0.481	**<0.01**	10.69	4.38-29.88
Connective tissue	1.641	0.288	**<0.01**	5.16	2.94-9.17
disorder	0.558	0.602	0.35	1.75	0.47-5.38
Arteriovenous fistula					
Amputation					
Ambulatory surgery (yes)	-0.423	0.094	**<0.01**	0.66	0.54-0.79
Operator's experience <	0.176	0.087	**0.04**	1.19	1.00-1.41
5years					
Fitzpatrick skin type†					
II	0.221	0.104	**0.03**	1.25	1.02-1.53
III	0.252	0.147	0.09	1.29	0.96-1.71
IV	0.102	0.224	0.65	1.11	0.70-1.70
V	0.440	0.445	0.32	1.55	0.60-3.55
VI	1.229	0.406	**0.00**	1.50	1.50-7.53
Surgical risk category†					
Intermediate	-0.151	0.114	0.19	0.86	0.69-1.08
High	0.701	0.121	**<0.01**	2.02	1.59-2.56
Visual appearance score†					
Poor: 0 to 30	2.973	0.138	**<0.01**	19.56	14.95-25.74
Moderate: 31 to 70	0.906	0.107	**<0.01**	2.48	2.01-3.06
Palpable appearance score†					
Poor: 0 to 30	3.339	0.144	**<0.01**	28.18	21.31-37.55
Moderate: 31 to 70	1.143	0.110	**<0.01**	3.14	2.53-3.90

ASA: American Society of Anesthesia Physical status, BMI: body mass index, calculated as weight in kilograms divided by height in square meters, reference level is 20-25 kg m^{-2} , PIVC: Peripheral intravenous cannula

Bold values represent P < 0.05

†Data were compared regarding the first item for ASA classification (ASA I), Fitzpatrick scale (Scale I), Surgical risk category (Low), Visual appearance score (71 to 100) and Palpable appearance score (71 to 100)

Items with a P<0.20 were refused from the multivariate model.

TABLE 4. Coefficient, standard error, z-value, p-value, odds ratio, 95% confident interval for the variables maintained after the backward stepwise multivariable logistic regression.

	Coefficient	**Standard Error**	**Z Value**	**P value**	**Odds Ratio**	**95% CI**
BMI						
< 20 kg m^{-2}	0.421	0.263	1.60	0.11	1.52	0.90-2.51
> 25 kg m^{-2}	-0.109	0.114	-0.95	0.34	0.90	0.72-1.12
History of						
Difficult PIVC insertion	2.121	1.53	13.91	**<0.01**	8.34	6.20-11.28
Cutaneous disorders	0.499	0.338	1.48	0.14	1.65	0.84-3.18
Surgical risk category						
Intermediate	-0.182	0.138	-1.32	0.19	0.83	0.64-1.10
High	0.5232	0.152	3.51	**<0.01**	1.70	1.27-2.29
Visual appearance score						
Poor: 0 to 30	0.988	0.235	4.20	**<0.01**	2.69	1.69-4.26
Moderate: 31 to 70	0.002	0.179	0.01	0.99	1.00	0.70-1.42
Palpable appearance score						
Poor: 0 to 30	2.098	0.234	8.95	**<0.01**	8.15	5.16-12.94
Moderate: 31 to 70	0.877	0.181	4.84	**<0.01**	2.40	1.69-3.44

CI = Confidence interval ; BMI: body mass index, calculated as weight in kilograms divided by height in square meters, reference level is 20-25 kg m^{-2} , PIVC: peripheral intravenous cannula,

Bold values represent P < 0.05

TABLE 5. VENSCORE and predicted first attempt failure rate of PIVC insertion

Risk Factor	Score
History of Difficult PIVC insertion	2 points
High-risk procedures	1 point
Visual appearance score	
Poor: 0 to 30	1 point
Palpable appearance score	
Poor: 0 to 30	2 points
Moderate: 31 to 70	1 point

VENSCORE	Failure rate
0	7%
1	17%
2	35%
3	60%
4	80%
5	92%
6	97%

VENSCORE is represented as a scoring system to calculate the predicted risk for an individual patient. Scores are added after answering a question with "yes".