Intensive Care Med (1991) 17:350–354

Intensive Care Medicine

Subclavian vein catheterization in critically ill children: analysis of 322 cannulations

J. Casado-Flores, A. Valdivielso-Serna, L. Pérez-Jurado, J. Pozo-Román, M. Monleón-Luque, J. García-Pérez, A. Ruiz-Beltran and M. A. García-Teresa

Pediatric Intensive Care Unit, Niño Jesús Hospital, Autónoma University of Madrid, Madrid, Spain

Received: 21 August 1990; accepted: 2 June 1991

Abstract. Complications in 322 percutaneous subclavian vein catheters placed in 272 children by the infraclavicular approach were investigated prospectively. Ages ranged from 4 days to 15 years. Incidents during catheter introduction occurred in 13 cases, and were more common when insertion was on the right side ($p<0.01$). Nine (2.8%) required urgent treatment: (6 pneumothorax, 1 hydrothorax, and 2 hemothorax). Anomalous lodging of the catheter tip was more common when insertion was on the right side ($p<0.05$). Complications during catheter maintenance were 3 venous thromboses, 3 catheter obstructions, and 7 migrations out of position. There was no significant difference in complications related to age. Catheter cultures were positive in 33 (17%) of 190 catheters cultured (27 through colonization and 6 through catheter-related sepsis). *Staph. epidermidis* was the organism most frequently isolated (19 cases; 58%). Catheterization time of more than 5 days and catheter-related sepsis were statistically associated ($p<0.05$). *Staph. epidermidis* isolation and duration of cannula use were statistically related ($p<0.01$). No catheter-related deaths occurred. We conclude that subclavian vein catheterization is a simple and useful procedure that entails relatively few serious complications when performed by experienced pediatricians.

Key words: Central subclavian catheter – Children – Catheter complications

The cannulation of a central vein in critically ill children is an extremely useful therapeutic technique as it allows: a) the administration of larger volumes of fluids in shorter times and at higher osmolarities than is possible by peripheral routes (rehydration, volume replacement, central parenteral nutrition, etc.); b) hemodynamic monitoring (CVP, PWP, etc.); and c) the rapid administration of drugs during cardiopulmonary resuscitation.

Since Aubaniac [1], and later Wilson et al. [2], described the technique of percutaneous subclavian vein catheterization (SCVC), its use has become so widespread that it is now an essential technique for the proper treatment of emergency situations. Although its acceptance has been complete in adult medicine [3], this is not so in pediatrics where there is concern about its potential complications [4–7].

We report a prospective study to determine and evaluate the technical difficulties, and the immediate and late complications, associated with the performance of SCVC in children of all ages by non-surgical pediatricians in both routine and emergency conditions.

Patients and methods

Our survey covered a total of 322 SCVCs carried out in 272 patients over an 8.5 year period (June 1981 to December 1989).

The patients' ages ranged from 4 days to 15 years (2.6±2.9 years), and their weights were from 1,750 g to 54 kg (12.3±8.8 kg). The age distribution was: 28 children (10%) less than 1-month-old, 78 (27%) between 1 and 12-months-old, 86 (32%) between 1 and 5-years-old, and 84 (31%) more than 5-years-old. Of the patients 68 (62%) were males and 104 (38%) were females (M/F = 1.6/1).

Admission to the pediatric intensive care unit (PICU) was for sepsis in most cases (129; 47%), respiratory failure (27; 10%), neurologic disorders (30; 11%), shock (25;9%), cardiorespiratory arrest (21; 8%), cardiac failure (18; 7%), renal failure (12; 4%), and others such as poisoning, malnutrition, and ketoacidosis (14;6%).

The indications for SCVC were classified into 5 groups: 1) need for hemodynamic monitoring, 2) lack of peripheral venous access, 3) parenteral nutrition, 4) cardiopulmonary resuscitation, and 5) other emergency situations.

SCVC was carried out in the PICU at patients' bedside by critical care pediatricians. Patients were placed in the 20° Trendelenburg position, the head was turned 90° to face away from the insertion point, and the homolateral arm was placed up against the trunk of the body. A pillow was placed under the shoulders. The supra- and infra-clavicular area was cleaned with a 10% povidone-iodine scrub, and the field was then surgically isolated. Except in cardiorespiratory arrest situations, the procedure was carried out with novocaine as local anesthetic. When the patient was extremely agitated, meperidine (0.5 mg/kg/i.v.) or midazolam (0.2–0.4 mg/kg/i.v. as necessary) was administered.

The infraclavicular route was used according to the technique described by Aubianac [1] and Wilson et al. [2]. If 3 attempts to perform the technique failed, or accidental puncture of the subclavian artery occurred, then cannulation of the contralateral vein was used. If this was

equally unsuccessful, the technique was abandoned and a different venous route was chosen. Vygon Centracath catheters between 22 and 16 g were used, the particular choice depending on the age, weight and size of the patient. The approximate length of the catheter to be inserted was estimated by external measurement of the catheter's theoretical path from the insertion point to the entrance of the right atrium. The catheter was fixed in place by suturing it to the skin. Anterior-posterior chest radiography was used to verify the position of the catheter tip. An additional lateral or contrast radiography was used when necessary. Correct placement was taken as being in the superior vena cava at the entrance to the right atrium. All manipulation was carried out under strict asepsis.

When signs of systemic infection appeared, cultures were done on peripheral blood and catheter blood. Catheter-related sepsis was defined as a catheter tip or blood culture yielding the same organism as peripheral blood culture, and the existence of clinical symptoms of sepsis for which no anatomical focus other than the catheter could be identified. Colonization was defined as no clinical signs of sepsis but positive catheter tip culture. All catheters were cultured upon removal (except those from patients who died with the cannula in place, and some of those removed very soon after insertion because of noninfectious complications). The reasons for catheter removal were: a) suspected catheter-related sepsis that did not respond to antibiotics, b) irreversible obstruction, with no blood return, c) extravascular migration of catheter tip, and d) disappearance of the reason for SCVC.

Our study analyzed patient characteristics, the indications for SCVC, the side on which the patient was cannulated, catheter residence time, and the mechanical and infectious complications attributable to the procedure.

Statistical methods

The statistical methods used were: the Kolmogorof-Smirnoff test, for analyzing the distribution of quantitative variables; the Mann-Whitney U test (MW) and Kruskal-Wallis test (KW), for nonparametric variables; and the χ^2 test or two-tailed Fisher exact test (FET 2t test), for qualitative variables with fewer than 5 cases per cell.

Results

We analyzed all those cases in which the subclavian vein was successfully cannulated. The number of attempts was not recorded but in no instance was it more than 3. In only 21 patients (not included in this study) was it necessary to abandon the technique and catheterize another vein (internal jugular, femoral, etc.). The success rate of the procedure was therefore 93%.

The most common indication for SCVC was hemodynamic monitoring (128 cases; 48%), followed by lack of peripheral venous access (61 cases; 22%), parenteral nutrition (36 cases; 13%) and cardiopulmonary resuscitation (33 cases; 13%). The technique was performed under routine conditions in 70% of the patients and under emergency conditions in the remaining 30% (cardiopulmonary resuscitation, status epilepticus, multiple trauma, etc.).

On 190 occasions (60%) SCVC was performed on the right side and on 132 occasions (40%) on the left side. Catheterization was maintained for an average of 4 days (mean $\pm$ SD = 4 $\pm$ 8), the maximum duration being 120 days. In 170 cannulations the duration was less than 2 days (53%), in 77 (24%) it was between 2 and 5 days, and in 75 (23%) it was more than 5 days.

In 259 SCVCs (80.5%) there were no complications. Incidents during the cannulation procedure (Table 1) were reported in 41 cases (13%). Only 9 cases required emergency therapeutic action (6 pneumothorax, 1 hydrothorax, and 2 hemothorax). On 7 occasions (2.2%) the subclavian artery was punctured without any immediate or late complications being detected. On 19 occasions (6%) anomalous catheter placement was observed. In the majority of these misplacements, the intravascular catheter migration was towards the homo- or contralateral internal jugular vein, and was more common when insertion was on the right side (R/L = 3.65/1), the difference being statistically significant ($p = 0.028$; FET 2t test). In 2 cases, rupture of the distal tip of the catheter occurred: once it lodged in the pleural space, and the other time it settled in an internal jugular vein obliging its surgical removal. Complications were more common during the cannulation procedure when the right subclavian vein was used (R/L = 3/1), the difference being statistically significant ($p = 0.0021$; FET 2t test).

During the time the catheters were in place in patients (Table 2), there were "mechanical" complications in 21 cases (6.5%): only 2 were serious (hydrothorax); the rest (accidental removal of catheter, obstruction, thrombosis, etc.) did not seriously affect the patients' evolution, more often than not resulting only in the loss of the access route.

No significant relation was found between the frequency of non-infectious complications and age

Table 1. SCVC: Complications during the cannulation procedure

	Total cannulations		Right side cannulations		Left side cannulations	
	$n = 322$	%	$n = 190$	%	$n = 132$	%
Pneumothorax	6	1.8	4	2.1	2	1.5
Hydrothorax	1	0.3	1	0.5	–	–
Hemothorax	2	0.6	2	1.5	–	–
Punction subclavian artery	7	2.2	6	3.2	1	0.75
Arrhythmias	5	1.5	3	1.6	2	1.5
Anomalous placement	19	6	16*	8.4	3	2.3
Rupture	2	0.6	2	1.05	–	–
Total complications	42	13	34**	17.9	8	6

*$p = 0.028$, **$p = 0.0021$ (Fisher exact test-two tailed)

Table 2. SCVC: Non-infectious complications during maintenance

	Total cannulations		Right side cannulations		Left side cannulations	
	$n = 322$	%	$n = 190$	%	$n = 132$	%
Thrombosis	3	0.9	1	0.5	2	1.5
Obstruction	3	0.9	2	1.1	1	0.75
Hydrothorax	2	0.6	2	1.1	–	–
Removal	7	2.2	4	2	3	2.3
Perforation	3	0.9	–	–	3	2.3
Other	3	0.9	2	1.1	1	0.75
Total complications	21	6.5	11	5.8	10	7.6

Table 3. Bacteriological analysis of positive cultures

	Positive culture catheter		Coinciding blood culture (catheter related sepsis)	
	$n = 33$	%	$n = 6$	%
Staph. epidermidis	19	58	2	33
C. albicans	3	9	1	16
Enterococcus	3	9	–	–
E. coli	2	6	1	16
S. Marcenses	2	6	1	16
Stp. viridans	1	3	1	16
Staph. aureus	1	3	–	–
Acitenobacter	2	6	–	–

($p = 0.371$; MW test), or weight ($p = 0.272$; MW test), although such complications were significantly related to catheter duration ($p = 0.0116$; MW test). Nor did the complications appearing after catheter insertion under emergency conditions (shock or resuscitation) show any significant difference with respect to the total ($p = 0.37$; MW test).

Cultures of the tips of 190 catheters were positive in 33 cases (17%). A significant relation existed between the duration of cannula use and the incidence of positive cultures ($p > 0.0185$; MW test). Colonization was seen in 27 instances (14% of cultured catheters and 82% of positives). Catheter-related sepsis was seen in 6 instances (3% of cultured catheters and 18% of positives). In all of them the catheter had been in place more than 5 days ($p = 0.016$; FET 2t test).

The microbial agent most commonly isolated was *Staph. epidermidis* (19 cases; 58%), well ahead of *C. albicans* and *Enterococcus*. The colonized catheters were also found to have been mostly invaded (17 cases; 63%) by *Staph. epidermidis*. In catheter-related sepsis, all the above agents were found, with no single organism predominating (Table 3). Examination of the overall figures for the different microorganisms shows that only the isolation of *Staph. epidermidis* is significantly related to duration ($p = 0.007$; MW test).

The total number of complications, including infectious complications, was 69 (21.4%). If we examine the complications attributable to the insertion technique (setting aside the others as having causes common to all intravascular catheters), we find that only 9 required immediate therapeutic action (2.8%). There were no deaths directly attributable to subclavian venous cannulation in our study.

Discussion

The success rate for subclavian vein catheterization fluctuates between 80% [8] and 96% [9]. In our series the success rate was similar (93%).

Immediate complications, almost always serious and requiring emergency treatment, appear during catheter insertion [10–13]. The frequency of serious early complications varies from 0.1% [14] to 1.33% [15] for pneumothorax, and from 0.1% to 0.4% for hemothorax [16], depending on the series. In our patients, the most common complication was pneumothorax (6 cases; 1.8%). Hemothorax occurred in 2 patients (0.6%) with pre-existing alterations in coagulation (hemolytic-uremic syndrome, and consumption coagulopathy associated with meningococcemia), which in no way constituted contraindications to cannulation. None of these complications had fatal consequences, being rapidly resolved in a few hours by appropriate treatment.

Anomalous lodging of the catheter tip has been observed with a frequency from 9% – 19% depending on the series [9, 14, 15], our result being 6%. We found it occurred more frequently when cannulation was on the right side. This commonly reported complication [17] can be attributed to the anatomical position of the brachiocephalic venous trunks, which facilitates a higher incidence of anomalous vascular lodging when the right subclavian vein is used [18]. Incorrect positioning of the catheter tip may produce serious complications [19, 20]. The appearance of alterations in heart rate due to stimulation by a catheter tip lodged in a heart chamber is a relatively common complication in children [6, 11]. In our patient population, the incidence of this complication was low (1.5%). Only on 4 occasions ventricular extrasystoles were detected, and these disappeared when the catheter was moved for repositioning in the correct place.

A higher incidence of immediate complications was observed when cannulation of the right subclavian vein was attempted. Although previous studies have suggested that SCVC cannot be performed safely in emergency situations [21], we found no significant difference in immediate complications in spite of the fact that 30% of our insertions were made under emergency conditions, in patients in advanced shock or in cardiorespiratory arrest. When inexperienced personnel catheterize patients, the failure and complication rates during the procedure are doubled. It is therefore recommended that novices begin training on unconscious or mechanically ventilated patients [22].

During SCVC maintenance in pediatric patients, the incidences of thrombosis and hydrothorax are 1.5% and 2.2%, respectively [5]. In our series the incidence of venous thrombosis was less than 1%, always in patients who had the catheter in place for more than 10 days. On 2 occasions (0.6%) hydrotorax was detected between the second and the fifth day after catheter placement.

Minor complications, i.e., those resulting in loss of the catheterization route, were rare. In 7 cases (2.2%) accidental catheter removal occurred, in 3 cases (0.9%) the precipitation of infused fluids produced irreversible catheter obstruction, and three times (0.9%) the catheter broke at a point outside the patient.

Almost all mechanical complications can be prevented or minimized by: 1) using safe perfusion pumps to guarantee a continuous flow during the time the route is in use, 2) taking care to avoid the infusion of chemically unstable and/or excessively hypertonic solutions. Catheter obstruction through precipitation can be cleared by the infusion of 0.2 – 0.5 ml of 0.1 M HCl [23].

Venous thrombosis is related with three factors: 1) prolonged catheterization, 2) low flow rates, and 3) use of hypertonic solutions [24–26]. The "in situ" infusion of fibrinolytic agents followed by heparinization has proved to be useful in the treatment of catheterization-related venous thrombosis [27].

We prefer to use the subclavian vein because for us it is the fastest, safest and most familiar route, although in children its diameter is similar to that of the internal jugular [28]. Some authors have found that in critically ill children the catheterization of the internal jugular leads to fewer complications than the use of other central paths [29]; others, however, find no difference [22]. The central path was recommended by Ereola et al. [14] after they performed 13,557 central catheterizations, 93% of them subclavian. It is accepted that the best path is the one you are most used to, and that each team should use the path if feels most confident about. Exceptions to this rule are thrombocytopenia, coagulation disorders, and respiratory failure, where the subclavian vein must be avoided.

We always use the infraclavicular route because for us it is the best-known and safest, the infra- and supraclavicular approaches having been shown to produce the same complications [8].

Catheter-related infections are one of the most important and common late complications in all intravascular invasive procedures [11–13, 26, 30]. The incidence of catheter-related sepsis in large pediatric series varies from 1.4–5.8% (5.13), and our results fall within this range (3%). The most frequently isolated pathogenic agent is *Staph. epidermidis* [5, 12], with an incidence of 28% [12], and our findings agree with this. It is well-known that most catheter-related infections result from contamination of the catheter system by saprophytic skin bacteria, especially *staphylococci* [31]. The greater incidence of coagulase negative staphylococci compared to other cutaneous saprophytes may be due to the ability of *Staph. epidermidis* to adhere to and colonize plastic surfaces [32, 33] and its greater capability to elude the bactericidal action of blood [34].

Many studies have demonstrated a higher incidence of catheter-related sepsis when the duration of catheterization is longer than 4 days [30, 35, 36]. The incidence of catheter-related sepsis in our series was statistically significant ($p < 0.01$) in patients cannulated longer than 5 days. The finding of a significant relationship between catheter duration and *Staph. epidermidis* isolation may be due to the variety of microorganisms found and their low individual frequency except for *staphylococcus*. Some studies of catheterization during long-term parenteral nutrition have failed to establish a clear relation between the duration of catheter use and the appearance of associated infections [37, 38]. This may have been because strict a catheter-care plan was followed. In short, the relationship between infection rate and duration of catheterization has not yet been clearly established.

Our patient population did not exhibit any of the other serious complications described in SCVC [18] such as cardiac perforation, thoracic duct lesions, and phrenic nerve and cervical sympathetic nerve lesions. Nor was there mortality directly related to SCVC.

In conclusion, percutaneous subclavian vein catheterization is a procedure that has become almost essential for the satisfactory handling of critically ill children. It can be performed easily, with relatively few serious complications, by trained non-surgical pediatricians in both routine and emergency situations, independently of the age and weight of the patient. It seems safer to choose initially the left subclavian vein because of the lower incidence of complications. A complete and rigorously defined procedure setting out all the steps, including the indications for withdrawal of the catheter, is necessary for the prevention and treatment of the possible complications.

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Dr. J. Casado-Flores
Hospital del Niño Jesus
Av. Menendez Peloyo, 65
E-28009 Madrid
Spain