

Percutaneous subclavian central venous catheterization in children and adolescents: success, complications and related factors

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Abstract

Objective: The objective of this study was to investigate the rates of success and of complications of percutaneous subclavian central venous catheterization in children and adolescents and to identify factors associated with them.

Methods: This was a study of a series of 204 percutaneous subclavian central venous catheterizations of children and adolescents, using polyvinyl chloride catheters (Intracath®), at the Instituto Materno-Infantil Professor Fernando Figueira between December 1, 2003 and April 30, 2004. An analysis was performed of variables related to the patient, such as age, and of variables related to the procedure such as success/failure, type of anesthesia, complications, who performed the procedure and the number of attempts needed.

Results: Overall, 89.2% of catheterizations were successful. Percentage success rates were significantly greater when percutaneous subclavian central venous catheterization was performed with the child sedated (94%). Around 43.2% of subclavian catheterizations progressed with complications related to insertion of the catheter; however, complications of greater severity were observed in just 3.5% of cases. There were a greater number of complications related to percutaneous subclavian central venous catheterizations performed by a first-year resident (58.8%), who performed a significantly greater percentage of procedures on children younger than 1 year and who also made a greater number of attempts per patient.

Conclusions: The chance of success was greater when patients were sedated for catheterization. There was a greater chance of complications related to insertion of the catheter when percutaneous subclavian central venous catheterization was performed by less experienced physicians, and it would be prudent to designate those central venous catheterizations that present greater risk to surgeons with greater experience in the experience.

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Introduction

Central venous catheters allow long-term venous access and have several indications in children, such as for monitoring central venous pressure and for delivering chemotherapy, parenteral nutrition and prolonged antibiotic therapy.¹⁻³ Filston & Grant state that, ever since the first descriptions of the technique appeared during the seventies, by Morgan & Harkins and Groff & Ahmed, use of the percutaneous access to the subclavian vein has

increased with children.⁴ Nowadays the procedure is routine in pediatric intensive care units.^{1,5,6}

In the USA 5 million central venous catheters are used annually.⁷ This type of information is not available on children in Brazil. Due to the lower costs, many Brazilian hospitals still use polyvinyl chloride catheters (Intracath[®]) which are more rigid, have a larger caliber needle and are not inserted using the Seldinger technique, which can predispose towards an increased number of complications.⁴

Although the literature considers this to be a safe procedure in children, it is subject to complications, such as pneumothorax, hemothorax, arterial puncture, arrhythmia, ill-positioned catheters and infection.^{1,3,8-10} In the literature consulted, complication rates varied from 0.7 to 30%,^{2,11-13} with only a small proportion of these endangering the lives of patients; however, these complications can increase the length and cost of hospital stays.¹⁴

Methods

This is a descriptive study of a case series, enrolling children and adolescents subjected to percutaneous puncture of the subclavian vein at the Instituto Materno-Infantil Professor Fernando Figueira (IMIP), in the city of Recife, in the Northeast of Brazil, between December 1, 2003 and April 30, 2004.

All children and adolescents who had been subjected to insertion of a polyvinyl chloride catheter (Intracath[®]) by means of percutaneous subclavian central venous catheterization during the study period were invited to take part. Cases were excluded if the procedure had been performed by a pediatrician or a resident in pediatrics, if a different type of catheter had been used or if venous dissection was employed.

The central venous catheterization procedure was performed on all patients using a technique similar to that described by Chaves.¹⁵ Positioning of the catheter was assessed by measurement against a guide, which is the same length as the catheter, from the point of entry through the skin up to the entrance of the right atrium. Chest X-rays were taken after the procedure to assess catheter positioning and the occurrence of complications. Catheters were considered well-positioned when it was located between the superior vena cava and the right atrium.

Catheterizations were performed by pediatric surgery residents and by pediatric surgeons working in the operating room, except in cases that were at risk from transport due to clinical severity. Procedures were carried out under sedation, with the exception of patients who had not fasted long enough, cases in which clinical severity did

not permit it and when the anesthetist was not available. Patients were sedated with halothane by the anesthetist. In cases in which procedures were performed under local anesthetic, lidocaine was used at 1%.

Success was defined as when the subclavian vein was catheterized percutaneously with no need for venous dissection. The following were defined as complications related to insertion of the catheter: pneumothorax, hemothorax, hydrothorax, ill-positioned catheter, diaphragmatic paralysis, bleeding and hematoma at the point of puncture and fracture of catheter.

Data were collected by the treating physician soon after the central venous access procedure and completed after the result of chest X-ray by a second surgeon, who was the same person for all of the cases studied. A questionnaire containing closed questions was used to collect data on the following variables: age, weight, sex, reason for catheterization, success/failure, number of attempts, number of locations attempted, who performed the procedure, the location where the procedure was performed, the type of anesthesia employed, complications and treatment of complications.

The software program Epi-Info version 6.04 (CDC, Atlanta) was used for data entry and statistical analysis. The chi-square test was employed to detect associations between categorical variables, with Yates' correction for binary tables. Fisher's exact test was used when indicated, and the level of significance adopted was $p \leq 0.05$.

The project was approved by the Research Ethics Committee at the IMIP, being in conformity with the Helsinki Declaration and its revisions. Free and informed consent was requested from children's guardians.

The objective of this study was to investigate the frequency of success and of complications related to percutaneous subclavian central venous catheter insertion in children and adolescents, and also to identify factors associated with these outcomes.

Results

Thirty-two of the 190 eligible patients did not take part in the study because their guardians refused to sign the consent form. Of those who did take part, 126 were subjected to central venous access once and 32 underwent more than one central venous access procedure during the study period, making a total of 204 percutaneous subclavian central venous catheterizations. For each procedure a questionnaire was filled out and subsequent procedures were considered separate cases irrespective of whether the same patient had been catheterized previously.

Patients' ages varied from 1 day to 18 years, with a median of 5 months. A majority of the patients were aged from 1 to 12 months (51.5%). Weight varied from 1.9 to 48.7 kg, with median of 5.8 kg, and patients weighing less than 5 kg predominated (46.1%). The percentage of male patients was discretely larger (55.9%). The most common reasons for requesting central venous access were prolonged antibiotic therapy (39.7%) and problems with peripheral venous access (36.7%).

We were successful in 89.2% (182/204) of percutaneous subclavian central venous catheterizations. In the majority of cases, insertion was attempted at just one location and access obtained at the first attempt (Table 1). Sedation was administered to 57.4% of the patients, and the principal reason for it not being used with the other patients was clinical severity (52.9%).

The majority of percutaneous subclavian central venous catheterizations were performed by second and third year pediatric surgery residents and took place in theatre (Table 1).

When the factors associated with successful percutaneous subclavian central venous catheterization were analyzed, it was found that success rates were

significantly higher when percutaneous subclavian central venous catheterizations were performed with patients sedated (94.0%), when compared with those percutaneous subclavian central venous catheterizations performed under local anesthetic (82.8%) ($p = 0.02$). No relationships were detected between success and age, weight, sex or who performed the operation (Table 2).

Complications related to the insertion of the catheter in 197 central venous access procedures were evaluated, it not being possible to analyze seven cases due to death of the patient before the control X-ray could be taken or because the image was of such poor quality that it was impossible to assess catheter positioning. Complications were detected in 43.2% of percutaneous subclavian central venous catheterizations (85/197). Seventy-eight percutaneous subclavian central venous catheterizations involved a single complication, while seven suffered more than one.

Just 3.5% (7/197) of percutaneous subclavian central venous catheterizations exhibited complications with clinical repercussions required intervention, being four cases of pneumothorax (2%), two of hemothorax (1%) and one of hydrothorax (0.5%).

Three of the four pneumothorax cases were subjected to closed pleural drainage. Two of these had been in critical

Table 1 - Characteristics of percutaneous subclavian central venous catheterizations carried out on children and adolescents at the IMIP (2004)

Variables	n (n = 204)	%
No. locations attempted		
1	161	78.9
2	33	16.2
3	6	2.9
4	4	2.0
No. attempts at puncture		
1	100	49.0
2 and 3	51	25.0
≥ 4	53	26.0
Person performing puncture		
R1	34	16.7
R2	69	33.8
R3	66	32.3
Surgeon	35	17.2
Place catheterization performed		
Operating room	141	69.1
Ward	31	15.2
ICU	26	12.7
ER and maternity	6	3.0

ICU = intensive care unit; IMIP = Instituto Materno-Infantil Professor Fernando Figueira; R1 = first-year resident; R2 = second-year resident; R3 = third-year resident.

condition at the time of percutaneous subclavian central venous catheterization and died. Just one of the pneumothorax cases was not drained, since the condition was only identified after death of the patient when X-rays were reviewed. The two patients with hemothorax were subjected to pleural drainage, and the hydrothorax case was managed using thoracentesis.

Incorrect catheter positioning was the most common complication, occurring in 28% of cases (55/197). Other complications were: localized bleeding, 14 cases (7.1%); punctured arteries, eight cases (4%); local hematoma, five cases; fractured catheter, two cases; and diaphragmatic paralysis ipsilateral to the puncture, one case. Just one ill-positioned catheter had to be removed, while the other 12 catheters were repositioned. All cases of bleeding at the point of puncture, hematoma and arterial puncture were treated conservatively.

When the factors associated with complications were analyzed, a higher percentage occurred when the procedure was carried out by the first-year resident (58.8%), compared with the other residents or fully qualified surgeons (39.9%), with a borderline level of significance ($p = 0.06$). No statistically significant

associations were observed between complications and any of the other factors studied (Table 3).

When those percutaneous subclavian central venous catheterizations that had been performed by the first-year resident were analyzed in isolation, we observed that they included a significantly greater frequency of catheterizations of children aged less than 1 year ($p = 0.04$) and that a larger number of attempts were made per patient ($p = 0.04$) (Table 4).

Discussion

The percutaneous subclavian central venous catheterization success rate observed in our study was comparable with figures for children in the literature, which vary from 71 to 100%.^{3,4,9,10,12,13,16}

Performing the procedure with the patient sedated resulted in greater success rates than carrying out catheterization with the patient conscious. We believe that rendering the patient immobile facilitates the identification of anatomical points and prevents the needle from becoming displaced from the vein during introduction of the catheter, increasing the success rate.

Table 2 - Factors associated with successful percutaneous subclavian central venous catheterization of children and adolescents at the IMIP (2004)

Variables	Success				p
	Yes (n = 182)		No (n = 22)		
	n	%	n	%	
Age (months)					
< 1	31	86.1	5	13.9	0.32
1-12	97	92.4	8	7.6	
≥ 13	54	85.7	9	14.3	
Sex					
Male	103	90.4	11	9.6	0.71
Female	79	87.8	11	12.2	
Weight (kg)					
≤ 5	83	88.3	11	11.7	0.41
5.1-10	65	92.9	5	7.1	
≥ 10.1	34	85.0	6	15.0	
Type of anesthesia					
General	110	94.0	7	6.0	0.02
Local	72	82.8	15	17.2	
Person performing puncture					
R1	28	82.4	6	17.6	0.22*
Others	154	90.6	16	9.4	

IMIP = Instituto Materno-Infantil Professor Fernando Figueira; R1 = first-year resident.

* Fisher's exact test.

The observed frequency in this study of percutaneous subclavian central venous catheterizations that involved complications related to insertion of the catheter (43.2%) was well above the level described in the literature, which is between 3.1 and 23% of percutaneous subclavian central venous catheterizations in children.^{1,9,10,12,13,17-19} We noted that the cause of this elevated incidence was the number incorrectly positioned catheters (28%). Other authors describe this type of complication in around 5 to 8% of percutaneous subclavian central venous catheterization series in children.^{1,9,13,18}

This difference can in part be explained by the fact that some of these studies used radioscopy during catheter insertion, which reduces the incidence of this complication.

We did not use the technique because it is not available at our hospital. Another fact that attracts attention is that almost half of the ill-positioned catheters were found in the right atrium or ventricle, demonstrating that the surgeon had failed to correctly using the guide to measure the catheter.

Despite the incidence of complications being elevated, the number of more serious complications, such as pneumothorax, hemothorax and hydrothorax, was similar to reports in the literature consulted, which vary from 0.4 to 3.4%.^{1,9,10,18,19}

Pneumothorax is a complication that can put patient's art risk of death, and its incidence in the literature varies from 0.2 to 2.4%.^{1,9,10,18,19} In our study, this complication

Table 3 - Factors associated with complications during insertion of percutaneous subclavian central venous catheters in children and adolescents at the IMIP (2004)

Variables	Complications during insertion of catheter				p
	Yes (n = 85)		No (n = 112)		
	n	%	n	%	
Age (months)					
< 1	17	48.6	18	51.4	0.76
1-12	43	42.6	58	57.4	
≥ 13	25	41.0	36	59.0	
Sex					
Male	48	43.2	63	56.8	0.90
Female	37	43.0	49	57.0	
Weight (kg)					
≤ 5	45	48.9	47	51.1	0.17
5.1-10	22	33.8	43	66.2	
≥ 10.1	18	45.0	22	55.0	
Type of anesthesia					
General	53	46.5	61	53.5	
Local	32	38.6	51	61.4	
Person performing puncture					
R1	20	58.8	14	41.2	0.06
Others	65	39.9	98	60.1	
No. locations attempted					
1	64	41.6	90	58.4	0.57
2	17	51.5	16	48.5	
≥ 3	4	40.0	6	60.0	
No. attempts at puncture					
1	36	37.5	60	62.5	0.29
2-3	24	49.0	25	51.0	
≥ 4	25	48.1	27	51.9	
Side punctured					
Right	47	42.0	65	58.0	0.89
Left	25	39.7	38	60.3	

IMIP = Instituto Materno-Infantil Professor Fernando Figueira; R1 = first-year resident.

occurred in 2% of cases, a similar incidence to that observed by Azevedo et al., in 85 percutaneous subclavian central venous catheterizations of children less than 1 year old and using a similar catheter to us (Intracath),¹ and also by Bonventre et al., in 282 percutaneous subclavian central venous catheterizations of children of varying ages.¹³

It is important to identify factors associated with increased complication rates in order that these may be reduced and the patient benefit. We observed a higher rate of complications related to percutaneous subclavian central venous catheterization when performed by a first year pediatric surgery resident. According to work by Venkataraman et al. and Sznajder et al., all of the surgeons and residents at our center could be considered experienced in the procedure since they had all performed more than 50 percutaneous subclavian central venous catheterizations of children.^{12,20} It is possible that this parameter for defining experience should be reassessed, although it has not been adopted as a rule.

The first-year resident had less experience than the other residents and surgeons, and we believe that this fact is directly related to the increased number of complications observed.

Some authors have described increased complication incidence rates related to percutaneous subclavian central venous catheterizations performed by less experienced physicians. Sznajder et al. observed greater numbers of complications in percutaneous subclavian central venous

catheterizations performed by inexperienced physicians. Lack of central venous puncture experience was also identified by Venkataraman et al. as a factor associated with higher rates of complications.¹² A study of 1,257 central venous punctures in children did not detect differences in relation to the experience of the person performing the procedure, and attributed this observation to the fact that more than 99% of these percutaneous subclavian central venous catheterizations had been performed under general anesthetic or profound sedation.¹⁰

Although we did not observe differences in the number of complications related to the use of sedation or not, another author observed that inexperienced physicians had half the rate of complications when percutaneous subclavian central venous catheterizations were performed on unconscious patients.²⁰ It would be an improvement if physicians beginning their training in puncture of the subclavian vein in children carried out the procedure with their patients sedated.

Our first-year resident performed more percutaneous subclavian central venous catheterizations on infants and made a greater number of puncture attempts per patient. Other studies have related multiple attempts (more than two) with increased numbers of complications. Venkataraman et al. studied 100 percutaneous subclavian central venous catheterizations performed by pediatricians and pediatric residents, reporting that the number of attempts was the factor that had the greatest influence on

Table 4 - Associations between which health professional performed catheterization and the characteristics of their patients and the procedures performed at the IMIP (2004)

Variables	First-year resident (n = 34)		Others (n = 170)		p
	n	%	n	%	
Age (months)					
≤ 12	29	85.3	112	65.9	0.04
> 12	5	14.7	58	34.1	
Weight (kg)					
≤ 5	18	52.9	76	44.7	0.42
5.1-10	12	35.3	58	34.1	
≥ 10.1	4	11.8	36	21.2	
Type of anesthesia					
General	16	47.1	101	59.4	0.25
Local	18	52.9	69	40.6	
No. attempts at puncture					
≤ 3	20	58.8	131	77.1	
≥ 4	14	41.2	39	22.9	0.04

IMIP = Instituto Materno-Infantil Professor Fernando Figueira.

complications. Around 86% of the complications in that series took place when more than two attempts at puncture were made.¹² A more recent study analyzed 1,257 percutaneous subclavian central venous catheterizations in children and also identified multiple puncture attempts with a single patient as a factor associated with increased numbers of complications.¹⁰

more recently, research into central venous access has aimed to increase success rates and reduced complications. This objective can be attained by means of puncture techniques guided by ultrasound or Doppler and new types of catheter, such as the peripherally inserted central type (PICC).

We conclude that puncturing the subclavian vein with the patient sedated increases the chances of success. Added to this is the factor some authors have reported lower complication rates related to procedures performed by less experienced physicians when the patient is sedated, in addition to pediatricians being well informed about these facts and receive instruction on the need for fasting before the procedure, with the objective that the great majority of percutaneous subclavian central venous catheterizations can be performed under general anesthetic.

In order to achieve the objective of reducing complication rates, radioscopy equipment is of great importance, as is the acquisition of peripherally inserted central catheters which involve lower risk of serious complications, such as pneumothorax, and also to reserve high-risk situations, such as conscious patients and infants, for more experienced physicians and to guarantee supervision for less experienced ones.

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