Evaluation of Mechanical Complications During Pediatric Central Venous Catheter Placement from 1994 to 2013

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Abstract: Pediatric central venous catheter placement could be associated with mechanical complications. Knowledge of detailed information described in case reports on such mechanical complications can help improve patient safety. Through an extensive literature search for case reports in PubMed and other databases from 1994 to 2013, 86 cases (from 63 articles) of mechanical complications related to pediatric central venous catheter placement were identified. Of the 86 patients, 22 died: 16 had tamponade; 3 had malposition, including migration, extravasation, and dislodgement; 1 had arterial puncture; 1 had hemothorax; and 1 had cardiac perforation. Cardiac tamponade was reported more frequently when umbilical catheters were used (23 cases) compared to cases where catheters were inserted at 13 other sites. Most of the cases of cardiac tamponade appeared to be related to the location of the catheter tip in the right atrium. Mechanical complications may lead to life-threatening outcomes. Therefore, the location of the tip of the central venous catheter should be assessed immediately after insertion, particularly in neonates, and any signs of abnormality should be identified as soon as possible to ensure appropriate management. Thus, we believe that awareness of the details of case reports on mechanical complications related to central venous catheter placement in children could help reduce the unfavorable outcomes.

Keywords: Pediatrics, Central venous catheters, Complication, Cardiac tamponade.

INTRODUCTION

The placement of pediatric central venous catheters (CVC) facilitates pressure monitoring, delivery of cardiovascular agents, and nutrition. These CVCs may be placed in the internal jugular vein (IJV), subclavian vein (SCV), femoral vein, external jugular vein, umbilical vein, or peripheral vein. However, complications may be unavoidable during CVC placement, irrespective of the route chosen.

The incidence of pediatric mechanical complications has been investigated in several studies [1-6]. These studies include the examination of a certain number of patients or review articles. In addition to these studies, we should also be aware of the detailed information that can be elucidated from case reports on the types of catheters and different tip positions, the treatment of the patients, and the outcomes, particularly in case reports on life-threatening complications. However, busy practitioners usually lack the time to read through large numbers of case reports, and to effectively obtain information on these complications.

In the present study, we searched for case reports of mechanical complications in PubMed and other databases, and extracted detailed information from those articles in order to review the complications during pediatric CVC placement.

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MATERIALS AND METHODS

In the present study, we performed an extensive literature search through PubMed, Google Scholar, and science journals to identify case reports in English dealing with mechanical complications during pediatric CVC placement. The following key words were used: children, pediatric, infant, neonate, central catheter, review, complications, internal jugular, common carotid, subclavian, femoral, external jugular, vertebral artery, thyrocervical trunk, transverse cervical artery, inferior thyroid artery, hemothorax, pneumothorax, chylopericardium, malposition, dural, arteriovenous fistula, pseudoaneurysm, foreign body, pinch-off syndrome, and arrhythmia. We excluded case reports with peripherally inserted central catheters, long lines, vascular intervention, cardiac catheterization, infection, and thrombosis.

In the mid-90s, Alderson *et al*. [7] introduced the use of a two-dimensional ultrasound scanner, whereas Kayashima and Fukutome [8] introduced the use of a small-caliber Doppler probe for the identification of the common carotid artery and the IJV for pediatric central venous catheter placement. We believe that the inadvertent arterial puncture associated with pediatric CVC placement has subsequently decreased due to the development of novel equipment. Therefore, we performed a search of case reports published during 2 decades (1994 to 2013). Unexpectedly, we identified several case reports on the occurrence of cardiac tamponade during CVC placement through the

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Table 1: Case Reports of Cardiac Tamponade During Pediatric Central Venous Catheter Placement

No	Author	Year	Age	Weight	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment	Out-come
9	Cherng *et al*.	1994	3 d	2994 g	IJV	5.5Fr, 3 lumen	RA	Cardiac arrest	PE	PCcentesis withdrawn	
10	Chang *et al*.	1995	0 d	1250 g	UVC	–	LA	Unmeasurable BP, bradycardia	RA interstitial edema	PCcentesis withdrawn	
11	van Engelenburg *et al*.	1998	15 d	–	SCV	PEL	RA	Died suddenly	Pericardial fluid	–	Died
			0 d	545 g	FV	22-G PU	Intracardiac	Respiratory distress, asystole	Enlarged heart, RA perforation	–	Died
			3 y	–	SCV	18-G PU	RA	Asystole	RA perforation	PCcentesis	Died
12	Jacobson *et al*.	1999	2 w	495 g	UVC	–	–	–	–	PCcentesis	
13	Pesce *et al*.	1999	0 d	2300 g	IJV	3Fr PU	RA	Respiratory distress	Pericardial fluid	–	Died
14	Darling *et al*.	2001	2 d	600 g	SCV	SL	–	Acute collapse	Peforated RA	–	Died
			1 d	1550 g	SCV	SL	–	Acute collapse	Peforated RA	–	Died
			3 d	1740 g	SCV	SL	–	Acute collapse	Peforated RA	–	Died
			2 d	890 g	Under IVC	PU	–	Acute collapse	–	PCcentesis	
			24 d	1130 g	Under IVC	SL	–	Subacute collapse	Tamponade	PCcentesis	
15	Lun *et al*.	2002	0 d	830 g	UVC	3.5Fr 1 lumen	T6-7	Tachycardia, hypotension	PE	PCcentesis withdrawn	
16	Madhok *et al*.	2002	0 d	3360 g	UVC	5Fr PV	Above diaphragm	Tachycardia, desaturation	PE	PCcentesis	
17	Onal *et al*.	2004	0 d	3450 g	UVC	5Fr PV	IVC–RA J	Tachypnea, cyanosis	PE, IVC perforation	Removal	
18	Traen *et al*.	2005	0 d	1470 g	UVC	PU 2 lumen	RA	Apnea, bradycardia, cardiac arrest	PE, perforated arterial wall	PCcentesis	
			0 d	1800 g	UVC	PU 1 lumen	RA	Cyanosis and bradycardia	PE	PCcentesis, removal	
			0 d	1380 g	UVC	PU 1 lumen	Outside RA	Bradycardia	PE	PCcentesis, removal	
19	Al Nemri *et al*.	2006	3 d	1620 g	UVC	–	Normal	Sudden collapse	Colored infusate	–	Died
			0 d	2975 g	UVC	5Fr PV	T6–T8	Sudden apnea, bradycardia, hypotension	Tip transition	PCcentesis withdrawn, removal	
20	Norris *et al*.	2006	16 y	–	SCV	9Fr Hickman	SVC	Desaturation, cardiac arrest	Thrombosis Tamponade	PCcentesis, removal	Died
21	Hong *et al*.	2006	1 d	1008 g	UVC	5Fr PV	T9	Desaturation, hypotension	PE	PCcentesis, removal	
22	Sehgal *et al*.	2007	0 d	580 g	UVC	–	Extracardiac above diaphragm	Weak pulse	PE	Removal	
23	Monteiro *et al*.	2008	2 d	3450 g	UVC	5Fr PU	IVC–RA J	–	PE, IVC perforation	PCcentesis	Died
			2 d	3725 g	UVC	4Fr PU	PA	Cardiac arrest	PE	PCcentesis	
24	Towbin	2008	12 y		IJV	7Fr PU	RA	Asystole	Cath bowed	Withdrawn PCcentesis, sternotomy	Died
25	Arya *et al*.	2009	6 d	2645 g	UVC	2 lumen	Normal	Tachycardia, desaturation	PE	Removal	
26	Alabsi	2010	0 d	1235 g	UVC	5Fr PU 2 lumen	T10	Respiratory distress, desaturation	–	PCcentesis, removal	

(Table 1). Continued.

No	Author	Year	Age	Weight	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment	Out-come
27	Megha *et al*.	2011	1 d	3350 g	UVC	SL	RA	Acute asystole	PE	Drainage	
28	Farry *et al*.	2012	33 d	–	SCV	–	Pericardial sac	Puffy left arm and face	–	Surgery	
29	Abdellatif *et al*.	2012	0 d	2400 g	UVC	SL	T7–8 RA	–	–	PCcentesis	
30	Warren *et al*.	2013	0 d	580 g	UVC	–	RA	–	RA edema	–	Died
			0 d	860 g	UVC	–	RA	–	No perforation, RA edema	–	Died
			0 d	580 g	UVC	–	RA	–	No perforation, RA epicardial exudate	–	Died
			0 d	671 g	UVC	–	–	–	RA discolored, no perforation	–	Died
			0 d	3142 g	UVC	–	RA wall lodged	–	–	PCcentesis withdrawn	Died

No, reference number; Year, published year; Cath, catheter; Tip, cath tip; –, not mentioned; A, artery; V, vein; y, years old; m, months old; w, weeks old; d, days old; IJV, internal jugular vein; EJV, external jugular vein; SCV, subclavian vein; SPV, saphenous vein; UVC, umbilical vein cath; SL, silastic; PEL, polyethylene; PU, polyurethane; PV, polyvinyl; CVAD, central venous access device; G, gauge; Fr, French size; RA, right atrium; LA, left atrium; PA, pulmonary artery; IVC, inferior vena cava; J, junction; T, thoracic vertebra level; T6-7, above diaphragm; T8–9, at diaphragm; T10, under diaphragm; PE, pericardial effusion; PCcentesis, pericardiocentesis; Removal, catheter removal.

umbilical veins, where the practitioners did not need to use ultrasound equipment.

Based on the results obtained through the PubMed search, we extended the search to Google Scholar, and science journals as well. After reviewing the titles and abstracts, we identified 63 articles related to mechanical complications during pediatric CVC placement.

RESULTS AND DISCUSSION

Through an extensive literature search for case reports in PubMed and other databases from 1994 to 2013, 86 cases (from 63 articles) of mechanical complications related to pediatric CVC placement were identified [9-71]. These included 36 cases of cardiac tamponade (Table **1**), 2 cases of cardiac perforation, 21 cases of malposition (of which 5 had dural injuries), 8 cases of arterial cannulation or puncture, 4 cases of hemothorax, 2 cases of chylopericardium, 4 cases of foreign bodies, 5 cases of pinch-off syndrome, 3 cases of arrhythmia, and 1 case of Horner syndrome (Table **2**). Catheters made from various materials were used in the cases of tamponade; 10 were polyurethane catheters, 6 were silastic catheters, 4 were polyvinyl catheters, 1 was a polyethylene catheter, and the catheter material was unknown in the other cases.

Of the 22 cases who died, 16 were neonates (age, <1 month; 72.7%), 2 were infants (age, 1–12 months; 9.1%), and 4 were children (age, >1 year; 18.2%). Deaths were most common in the cases with cardiac tamponade (16/37; 43%), followed by malposition (3/21; 14.3%). The complications reported were cardiac tamponade in 16 cases (72.7%), malposition in 3 (13.6%), arterial puncture in 1 (4.5%), cardiac perforation in 1 (4.5%), and hemothorax in 1 (4.5%). The tip of the CVC was in close proximity to the site of right atrial perforation, edema, or exudate in 13 of the 16 cases of cardiac tamponade where the patient died. Only 4 of the 16 tamponade patients who died were treated with pericardiocentesis (Table **3**).

Cases of cardiac tamponade were reported almost every year from 1994 to 2013 in the literature search conducted in the present study [9-30]. It was found that rigid polyethylene catheters were more likely to cause tamponade than the more flexible silicon and polyurethane catheters [11]. According to Weil *et al*., the catheter characteristics and the tip position of CVCs may be associated with an increased risk of cardiac tamponade [72]. In the present study, we also noted that catheters constructed from certain materials, such as polyurethane, silastic, and others, were associated with an increased risk of cardiac tamponade. The location of the catheter tip in the right atrium is considered as a risk factor for cardiac tamponade [14,30]. We noted that the CVC tip was reported to be in the right atrium in 89 (62.7%) of the 142 neonates who died [4].

In the present study, the death rates from cardiac tamponade related to the position of the CVC tip in the right atrium did not seem to decrease with time; these death rates did not significantly differ between the

Table 2: Case Reports of Complications other than Cardiac Tamponade During Pediatric Central Venous Catheter Placement

No	Author	Year	Complication	Age	Weihgt	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment	Out-come
31	Currarino *et al.*	1996	Malposition	1 d	–	IJV	SL (Port-A-Cath)	Superior intercostal V and JV	–	No perforation	–	Died
				13 y	–	SCV	SL (Port-A-Cath)	Superior intercostal V	–	Tip wedged	Withdrawn	
				3 w	–	IJV	Plastic	Thymic V	–	Mediastinal extravasation	Removal	
				5 m	–	IJV	SL (Port-A-Cath)	Azygos V	–	–	–	
				3.5 y	–	IJV	SL (Port-A-Cath)	Azygos V	–	Tip wedged, obstruction	–	
				4.5 y	–	SCV	SL (Port-A-Cath)	Azygos V	–	Mediastinal extravasation, thrombosis and stenosis	Removal	
32	Lussky *et al.*	1997		16 d	1145 g	SPV	SL 2Fr V-Cath®	Ascend lumbar V	–	–	Removal	
				3 d	1018 g	SPV	SL 2Fr V-Cath®	Ascend lumbar V	–	–	Removal	
33	Rajan *et al.*	1999		7 d	988 g	SPV	–	5th lumbar vertebra	Tonic-clonic movements	Cath posterior to lumbar vertebral column	Anti convulsant , removal	
34	Ghafoor *et al.*	2003		16 y	51 kg	SCV	3 lumen	Traversing the pleural cavity	–	–	Surgery	
35	Anderson *et al.*	2004		0	–	Scalp V	–	Cranial sutures	–	Shaking of the extremities	–	
				16 m	–	SCV	–	Somnolent	Seizure	Subdural hematoma, withdraw medical support	Surgery	Died
36	Chambers	2005		Neonate	2.9 kg	IJV	5Fr 3 lumen	Intercostal or azygos V	–	–	Withdrawa l	
37	Costa *et al.*	2008		0 d	1250 g	UVC	–	Meckel diverticulum	Umbilical cord cannulation	Pneumoperitoneum, perforated Meckel diverticulum	Surgery	
38	Yiğiter *et al.*	2008		0 d	1230 g	UVC	–	Liver parenchyma	Anemia	Hepatic laceration	Surgery	Died
39	Chhabra *et al.*	2008		16 m	–	IJV	5Fr	Extravasation	–	–	Surgical removal	
40	Skinner *et al.*	1995	Epidural or spinal malposition	11 w	5.2 kg	IJV	20-G Hydrocath	–	–	Blood not aspirated, extradural cath insertion below C6	Removal	
41	Miyamoto *et al.*	1996		16 d	4.0 kg	IJV	22-G	–	–	Clear liquid aspirated, cervical dural puncture	–	
42	Zenker *et al.*	2000		5 d	–	FV	–	–	–	Paravertebral and intraspinal		
43	Vidwans *et al.*	2000		11 d	965 g	SPV	2Fr SL Per-Q-Cath, Bard	–	–	Milky white fluid, spinal epidural space extravasation	Removal	
44	Fujita *et al.*	2006		9 m	5.2 kg	IJV	22-G 4F, 2 lumen	–	–	Intrathecal cannulation	Removal	

(Table 2). Continued.

No	Author	Year	Complication	Age	Weihgt	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment	Out-come
45	Skeehan	1993	Arterial puncture	26 m	11.5 kg	IJV	3Fr PEL	–	–	CCA cannulation to PA	Removal	
46	Cupitt	2000		0 d	–	SPV	23-G SL	–	Bradycardia, desaturation	PA perforation and bronchial erosion	Removal	
47	Eulmesekian *et al.*	2007		3 y	15.0 kg	IJV	–	–	Cardiac arrest, hemothorax	Internal mammary A laceration	–	Died
				7 y	30.0 kg	SCV IJV	7Fr	–	Shock, PCE	Internal mammary A laceration	Embolization	
48	Koklu *et al.*	2008		18 m	–	SCV	–	–	–	Mediastina mass, SA pseudoaneurysm	Surgery	
49	Chan *et al.*	2012		4 y	–	IJV	Implanted port	–	Lacunar infarct, Horner syndrome	Cath communication from IJV to CCA, carotid jugular arteriovenous fistula	Surgery after Removal	
50	Kayashima *et al.*	2012		1 y	7.1 kg	IJV	24 G	–	–	Vertebral arterial puncture	Pressure	
51	Kayashima	2013		15 m	7.5 kg	IJV	24 G	–	–	Transverse cervical artery puncture	Pressure	
52	Lovell *et al.*	2000	Hemothorax	22 m	10.7 kg	IJV	6-G Arrow	–	Hypotension	Brachial vein perforation suspected	Removal	Died
53	Hohlrieder *et al.*	2004		6 m	8.1 kg	SCV	5.5Fr 3 lumen	Next to SVC-subclavian junction	Bradycardia	Mediastinal hematoma and pleural fluid	Thoracostomy drainage	
54	Waddington *et al.*	2005		13 m	12.0 kg	IJV	5.5Fr 3 lumen	Mediastinal	Desaturation	Probably perforation with a dilator	Interpleural catheter	
55	Lu *et al.*	2008		6 m	–	SCV	4Fr 2 lumen	Left PA	Desaturation	PA cannulation, a hole in the PA	Surgical closure	
56	Kurekci *et al.*	1998	Chylopericardium	2 y	–	IJV	–	–	–	Chylothorax, right and left SCV occlusion	Drainage, heparin	
57	Alkayed *et al.*	2013		16 y	–	–	Broviac	–	–	with Chylothorax, thrombus in the IJV, innominate vein, and SVC	Removal	
58	Mupanemunda *et al.*	1992	Cardiac perforation	11 d	580 g	Axillary V	23-G SL	RA	–	Hydrothorax, RA perforation	–	Died
59	Wang *et al.*	2007		4 m	8.0 kg	IJV	8Fr	Too deep	–	Tip too deep, PE, cath protrusion and hole between the RA and IVC	Surgical closure	

(Table 2). Continued.

No	Author	Year	Complication	Age	Weihgt	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment	Out-come
60	Puvabanditsin *et al.*	2008	Foreign body	145 d	405 g	SPV	2.7Fr Broviac 1 lumen	IVC	Fracture 30 days after insertion	Cath fracture occlusion	Removal	
61	Tutar *et al.*	2009		8 m	7.0 kg	SCV	7Fr Hickman	–	Fracture during its removal after 3 months	Cath fragment embolization in the SVC	Removal	
				15 m	8.0 kg	–	7Fr Hickman	–	Fracture during its removal after 10 months	Cath fragment embolization in the SVC and RV	Removal	
62	Jiang *et al.*	2012		8 y	25 kg	IJV	5Fr 2 lumen	–	–	Guide wire fracture and retention	–	
63	Giretti *et al.*	2006	Pinch-off syndrome	2 y	11 kg	SCV	Port cath	SVC	Disconnection between Port catheter and reservoir	Migration to the left PA.	Removal	
64	Nuss *et al.*	2008		6 y	–	SCV	12Fr CVAD	–		Cath disruption	Removal	
65	Caruselli *et al.*	2009		7 y	–	SCV	6Fr Portcath	–	Reduced flow through the catheter after 22 months	One longitudinal lesion	Removal	
66	Eryilmaz *et al.*	2012		7 y	–	SCV	Implanted port	–	–	Pinch-off cath fragment embolization in the PA	Snare	
67	Gowraiah *et al.*	2013		11 y	–	SCV	6.6FR Port-A-Cath	–	After 3 y of insertion pain and swelling in right SCV area	Fragment into left PA	Retrieved	
68	Keohane *et al.*	1999	Arrhythmia	13 y	70 kg	IJV	–	–	–	Atrial fibrillation	Cardioversion	
69	Cephus *et al.*	2007		5 d	1945 g	FV	4Fr 2 lumen	IVC	Bradycardia	Transient complete atrioventricular block	Removal	
70	da Silva *et al.*	2010		14 d	3.7 kg	EJV	4Fr 2 lumen	–	–	Supraventricular tachycardia	Synchronized cardioversion	
71	Ford *et al.*	2007	Horner syndrome	19 m	13.5 kg	IJV	5Fr 2 lumen	–	–	Ptosis and meiosis	Removal	

No, reference number; Year, published year; Cath, catheter; Tip, cath tip; –, not mentioned; A, artery; V, vein; y, years old; m, months old; w, weeks old; d, days old; IJV, internal jugular vein; EJV, external jugular vein; SCV, subclavian vein; SPV, saphenous vein; SL, silastic; PEL, polyethylene; PU, polyurethane; PV, polyvinyl; CVAD, central venous access device; UVC, umbilical vein cath; G, gauge; Fr, French size; RA, right atrium; PA, pulmonary artery; IVC, inferior vena cava; PE, pericardial effusion; Removal, catheter removal.

Table 3: Cases of Death

No.	Author	Year	Complication	Age	Weihgt	Vessel	Cath or needle	CVC tip position	Episode	Complication details	Treatment
11	van Engelenburg *et al*.	1998	Cardiac tamponade	15 d	–	SCV	PEL	RA	Died suddenly	PE	–
				0 d	545 g	FV	22-G PU	Intracardial	Respiratory distress, asystole	Enlarged heart, RA perforation	–
				3 y	–	SCV	18-G PU	RA	Asystole	RA perforation	PCcentesis
13	Pesce *et al*.	1999		0 d	2300 g	IJV	3Fr PU	RA	Respiratory distress	PE	–
14	Darling *et al*.	2001		2 d	600 g	SCV	SL	–	Acute collapse	RA perforation	–
				1 d	1550 g	SCV	SL	–	Acute collapse	RA perforation	–
				3 d	1740 g	SCV	SL	–	Acute collapse	RA perforation	–
19	Al Nemri *et al*.	2006		3 d	1620 g	UVC	–	Normal	Sudden collapse	Colored infusate	–
20	Norris *et al*.	2006		16 y	–	SCV	9Fr Hickman	SVC	SpO2↓ Cardiac arrest	Thrombosis, tamponade	PCcentesis, removal
23	Monteiro *et al*.	2008		2 d	3450 g	UVC	5Fr PU	IVC–RA J	–	PE, IVC perforation	PCcentesis
24	Towbin *et al*.	2008		12 y		IJV	7Fr PU	RA	Asystole	Cath bowed	Withdraw, PCcentesis, sternotomy
30	Warren *et al*.	2013		0 d	580 g	UVC	–	RA	–	RA interstitial edema	–
				0 d	860 g	UVC	–	RA	–	No perforation, RA interstitial edema	–
				0 d	580 g	UVC	–	RA	–	No perforation, RA epicardial exudate	–
				0 d	671 g	UVC	–	–	–	RA discolored, no perforation	–
				0 d	3142 g	UVC	–	RA wall lodged	–	–	–
31	Currarino *et al*.	1996	Malposition	1 d	–	IJV	SL (Port-A-Cath)	Superior intercostal V and JV		PE, no perforation	–
35	Anderson *et al*.	2004		16 m	–	SCV	–	–	Somnolent, Seizure	Subdural hematoma, withdraw medical support	Surgery
38	Yiğiter *et al*.	2008		0 d	1230 g	UVC	–	Liver parenchyma	Hb drop	Hepatic laceration	Surgery
47	Eulmesekian *et al*.	2007	Arterial puncture	3 y	15.0 kg	IJV	–	–	Cardiac arrest, Hemothorax	Internal mammary artery laceration	–
49	Lovell *et al*.	2000	Hemothorax	22 m	10.7 kg	IJV	6-G Arrow	–	Hypotension	Vein perforation suspected	Removal
58	Mupanemunda *et al*.	1992	Cardiac perforation	11 d	580 g at birth	Axillary V	23-G SL	RA		Hydrothorax, RA perforation	–

No, reference number; Year, published year; Cath, catheter; Tip, cath tip; –, not mentioned; A, artery; V, vein; y, years old; m, months old; w, weeks old; d, days old; IJV, internal jugular vein; SCV, subclavian veinl; FV, femoral vein; UVC, umbilical vein cath; SL, silastic; PEL, polyethylene; PU, polyurethane; PV, polyvinyl; G, gauge; Fr, French size; RA, right atrium; J, junction; LA, left atrium; PA, pulmonary artery; PE, pericardial effusion; PCcentesis, Pericardiocentesis; Removal, catheter removal.

former and the latter half of the study period. Among 31 cases of cardiac tamponade, excluding 5 cases reported by Warren *et al*. (due to the lack of information on the study period), 7 of 15 patients and 4 of 16 patients died during the former and latter half of the study period, respectively (Fisher exact test, p = 0.273)

[14], despite the recommendations established by the U.S. Food and Drug administration in 2002 [73].

The appropriate location for an umbilical catheter is in the inferior vena cava (at the level of T9) or just below the right atrial entrance in the inferior vena cava [74]. For upper circulation CVCs, the ideal position of the CVC tip is at the SVC–right atrial junction [6]. The carina can be used as a landmark for CVC placement in children [75]. However, the positioning of the CVC tip based on a chest radiograph can be difficult, particularly in neonates, because the carina is not always located above the pericardium [76].

Cardiac tamponade developed despite the CVC tip being located outside the right atrium in 4 cases [18-20,25], of which 2 patients died.[19,20] Thus, cardiac tamponade should be strongly suspected in any neonate with an umbilical CVC who develops sudden or acute clinical cardiopulmonary deterioration, even when the catheter is appropriately placed [18,25]. The mortality due to pericardial effusion was 8% (3/37) in cases who received pericardiocentesis, compared to 75% (18/24) in cases who did not receive pericardiocentesis [77]. In the present study, we noted that an early diagnosis of cardiac tamponade followed by treatment using pericardiocentesis or removal could have saved 20 of the 36 patients. Moreover, the patients suitable for undergoing umbilical CVC placement should be carefully selected, and special precautions should be taken when an umbilical CVC is placed.

In a case of right atrial perforation, which resulted in sudden death without a diagnosis of cardiac tamponade, the tip of the CVC was placed in the right atrium [58]. Moreover, among the patients who died, the cardiac tamponade and perforated right atria were only identified on autopsy [11,14].

To prevent cardiac tamponade or right atrial perforation, the tip of the CVC should not be placed in the right atrium, and the CVC should be removed as soon as possible in cases where it is not required. The insertion of umbilical venous catheters with electrocardiography (ECG) guidance, connected to a conductive Johans ECG adapter in neonates, can avoid the need for radiography and enable quick intravenous access [78].

Catheters can migrate into various veins [31,32,36], and even the liver parenchyma [38]. The causes of death—pericardial effusion, liver laceration, and subdural hematoma—in the 3 patients [31,35,38] with malposition varied and were non-specific. To prevent complications related to malposition, early recognition and correction of a malpositioned catheter could be vital.

In the 4 cases with hemothorax in this analysis [52-55], upper body routes, including the IJV and SCV in 2 cases each, were used. However, the dilators might penetrate the vessels, as evidenced in certain cases [52,54]. Therefore, we should be aware that a straight guidewire, rigid catheter, or combinations of guidewires and dilators [55] can penetrate the brachiocephalic vein. In emergency cases, thoracotomy may be required in order to achieve hemodynamic recovery and identify the CVC tip position. To prevent the development of hemothorax, guidewires, catheters, and dilators should be cautiously advanced and should not be advanced to a great extent.

Thrombosis could play an important role in chylopericardium. A case of obstruction of the thoracic duct orifice due to thrombosis has been previously reported [56]; in another case, thrombosis resulting from the placement of multiple venous catheters increased the central venous pressure and caused chylopericardium [57]. To prevent and detect thrombosis that could potentially cause chylopericardium, early venography may be essential.

In addition, a foreign body is a rare but serious complication of pediatric CVC placement. The prolonged use of catheters, or their constant compression of the costoclavicular arch—known as “pinch-off” syndrome—results in the production of foreign bodies by catheter fractures, fragmentation, and distal embolization [66]. Pinch-off syndrome is the condition where a CVC is damaged or disrupted by the repeated mechanical compression between the clavicle and the homolateral first rib, and can occur after months or years of placement [65]. In the present study, foreign bodies or pinch-off syndrome was found to develop mainly in cases where the CVC has been placed for a long duration, from 1 month to 3 years. Prior to CVC placement, the patients and their parents should be informed about the potential for such remnants of fractures. To prevent pinch-off syndrome, alternative techniques such as the percutaneous supraclavicular technique, percutaneous internal jugular vein technique, and ultrasound-guided cannulation of the axillary vein, can be used [79].

In one case of arrhythmia, the excitable heart with cardiomyopathy was vulnerable to stimulation by a guidewire or catheter [68], and in another case of arrhythmia, CVC placement damaged the conduction system of the heart [69]. Cardioversion was effective in 1 case with atrial fibrillation [68] and 1 case with life-threatening supraventricular tachycardia [70]. To prevent arrhythmia, the guidewires or catheters need to be carefully inserted during CVC placement.

In the present study, we could identify only 1 case report of Horner syndrome associated with pediatric CVC placement [71]. It is an uncommon finding in pediatric patients and is rarely observed in the pediatric intensive care unit settings [80]. Moreover, the etiology of pediatric Horner syndrome varies. In such cases, the practitioners needed repeated attempts to puncture the IJV before blood aspiration was achieved, even though real-time ultrasound visualization of the IJV was employed [71]. Therefore, this syndrome needs to be promptly identified to initiate immediate treatment and avoid permanent damage to the neuronal pathway [81]. In addition, to prevent Horner syndrome, avoiding multiple puncture attempts and ultrasound visualization of the IJV may prove useful [71].

In conclusion, we analyzed many case reports of mechanical complications occurring during pediatric CVC placement. Mechanical complications may lead to life-threatening outcomes. Therefore, the location of the CVC tip should be assessed immediately after insertion, particularly in neonates. Moreover, any sign of abnormality should be detected as early as possible to initiate prompt and appropriate management. Awareness of the details of case reports of mechanical complications can help to decrease the number of unfavorable outcomes among such cases.

REFERENCES

[1] Mitto P, Barankay A, Späth P, Kunkel R, Richter JA. Central venous catheterization in infants and children with congenital heart diseases: experiences with 500 consecutive catheter placements. Pediatr Cardiol 1992; 13(1): 14-19.

[2] Casado-Flores J, Barja J, Martino R, Serrano A, Valdivielso A. Complications of central venous catheterization in critically ill children. Pediatr Crit Care Med 2001; 2(1): 57-62. http://dx.doi.org/10.1097/00130478-200101000-00012

[3] Cartwright DW. Central venous lines in neonates: a study of 2186 catheters. Arch Dis Child Fetal Neonatal Ed 2004; 89(6): F504-8. http://dx.doi.org/10.1136/adc.2004.049189

[4] Karapinar B, Cura A. Complications of central venous catheterization in critically ill children. Pediatr Int 2007; 49(5): 593-9. http://dx.doi.org/10.1111/j.1442-200X.2007.02407.x

[5] Askegard-Giesmann JR, Caniano DA, Kenney BD. Rare but serious complications of central line insertion. Semin Pediatr Surg 2009; 18(2): 73-83. http://dx.doi.org/10.1053/j.sempedsurg.2009.02.003

[6] Costello JM, Clapper TC, Wypij D. Minimizing complications associated with percutaneous central venous catheter placement in children: recent advances. Pediatr Crit Care Med 2013; 14(2): 273-83. http://dx.doi.org/10.1097/PCC.0b013e318272009b

[7] Alderson PJ, Burrows FA, Stemp LI, Holtby HM. Use of ultrasound to evaluate internal jugular vein anatomy and to facilitate central venous cannulation in paediatric patients. Br J Anaesth 1993; 70(2): 145-8. http://dx.doi.org/10.1093/bja/70.2.145

[8] Kayashima K, Fukutome. A reliable method for internal jugular vein catheterization for neonates and infants using a small-caliber Doppler probe. Masui 1996; 45(11): 1424-9.

[9] Cherng YG, Cheng YJ, Chen TG, Wang CM, Liu CC. Cardiac tamponade in an infant. A rare complication of central venous catheterisation. Anaesthesia 1994; 49(12): 1052-4. http://dx.doi.org/10.1111/j.1365-2044.1994.tb04354.x

[10] Chang LY, Horng YC, Chou YH, Tsou KI. Umbilical venous line related pericardial effusion in a premature neonate: report of a case. J Formos Med Assoc 1995; 94(6): 355-7.

[11] van Engelenburg KC, Festen C. Cardiac tamponade: a rare but life-threatening complication of central venous catheters in children. J Pediatr Surg 1998; 33(12): 1822-4. http://dx.doi.org/10.1016/S0022-3468(98)90296-2

[12] Jacobson Z, Strom J. Pericardial tamponade complicating central venous catheterization in an infant with very low birth weight: the role of echocardiography in diagnosis and treatment. Heart Dis 1999; 1(3): 133-5.

[13] Pesce C, Mercurella A, Musi L, Campobasso P, Negri M. Fatal cardiac tamponade as a late complication of central venous catheterization: a case report. Eur J Pediatr Surg 1999; 9(2): 113-5. http://dx.doi.org/10.1055/s-2008-1072224

[14] Darling JC, Newell SJ, Mohamdee O, Uzun O, Cullinane CJ, Dear PR. Central venous catheter tip in the right atrium: a risk factor for neonatal cardiac tamponade. J Perinatol 2001; 21(7): 461-4. http://dx.doi.org/10.1038/sj.jp.7210541

[15] Lun KS, Lee WH. Cardiac tamponade secondary to umbilical vein catheterization in a premature newborn: a case report. HK J Paediatr 2002; 7: 98-100.

[16] Madhok AB, Chabbra M, Lourdes C. Unusual complication of umbilical venous catheterization leads to pericardial tamponade. Internet J Pediatr Neonat 2002; 2(2).

[17] Onal EE, Saygili A, Koç E, Türkyilmaz C, Okumus N, *et al*. Cardiac tamponade in a newborn because of umbilical venous catheterization: is correct position safe? Paediatr Anaesth 2004; 14(11): 953-6. http://dx.doi.org/10.1111/j.1460-9592.2004.01385.x

[18] Traen M, Schepens E, Laroche S, van Overmeire B. Cardiac tamponade and pericardial effusion due to venous umbilical catheterization. Acta Paediatr 2005; 94(5): 626-8. http://dx.doi.org/10.1080/08035250410025492

[19] Al Nemri AM, Ignacio LC, Al Zamil FA, Al Jarallah AS. Rare but fatal complication of umbilical venous catheterization. Congenit Heart Dis 2006; 1(4): 180-3. http://dx.doi.org/10.1111/j.1747-0803.2006.00031.x

[20] Norris ML, Klaassen R. Central venous catheter thrombosis as a cause of SVC obstruction and cardiac tamponade in a patient with Diamond-Blackfan anemia and iron overload. Pediatr Blood Cancer 2006; 46(1): 112-4. http://dx.doi.org/10.1002/pbc.20368

[21] Hong EJ, Lee KA, Bae IH, Kim MJ, Han HS. Umbilical venous line-related pleural and pericardial effusion causing cardiac tamponade in a premature neonate: A case report. Korean J Pediatr 2006; 49(6): 686-90. http://dx.doi.org/10.3345/kjp.2006.49.6.686

[22] Sehgal A, Cook V, Dunn M. Pericardial effusion associated with an appropriately placed umbilical venous catheter. J Perinatol 2007; 27(5): 317-9. http://dx.doi.org/10.1038/sj.jp.7211678

[23] Monteiro AJ, Canale LS, Barbosa R, Méier M. Cardiac tamponade caused by central venous catheter in two newborns. Rev Bras Cir Cardiovasc 2008; 23(3): 422-4. http://dx.doi.org/10.1590/S0102-76382008000300023

[24] Towbin R. The bowed catheter sign: a risk for pericardial tamponade. Pediatr Radiol 2008; 38(3): 331-5. http://dx.doi.org/10.1007/s00247-007-0674-z

[25] Arya SO, Hiremath GM, Okonkwo KC, Pettersen MD. Central venous catheter-associated pericardial tamponade in a 6-day old: a case report. Int J Pediatr 2009; 2009: 910208.

[26] Alabsi S. Neonatal cardiac tamponade and pleural effusion resolved with chest tube placement. Neonatal Netw 2010; 29(6): 347-51. http://dx.doi.org/10.1891/0730-0832.29.6.347

[27] Megha M, Jain N, Pillai R. Pericardial tamponade in a newborn following umbilical catheter insertion. Indian Pediatr 2011; 48(5): 404-5.

[28] Farry PM, Paterson A. Perforation into the pericardial sac of an infant: a rare complication of central venous catheter insertion. Ulster Med J 2012; 81(1): 50-1.

[29] Abdellatif M, Ahmed A, Alsenaidi K. Cardiac tamponade due to umbilical venous catheter in the new born. BMJ Case Rep 2012; 13(7): 2012.

[30] Warren M, Thompson KS, Popek EJ, Vogel H, Hicks J. Pericardial effusion and cardiac tamponade in neonates: sudden unexpected death associated with total parenteral nutrition *via* central venous catheterization. Ann Clin Lab Sci 2013; 43(2): 163-71.

[31] Currarino G. Migration of jugular or subclavian venous catheters into inferior tributaries of the brachiocephalic veins or into the azygos vein, with possible complications. Pediatr Radiol 1996; 26(7): 439-49. http://dx.doi.org/10.1007/BF01377198

[32] Lussky RC, Trower N, Fisher D, Engel R, Cifuentes R. Unusual misplacement sites of percutaneous central venous lines in the very low birth weight neonate. Am J Perinatol 1997; 14(2): 63-7. http://dx.doi.org/10.1055/s-2007-994099

[33] Rajan V, Waffarn F. Focal neurological manifestations following aberrant central venous catheter placement. J Perinatol 1999; 19(6): 447-9. http://dx.doi.org/10.1038/sj.jp.7200207

[34] Ghafoor AU, Mayhew JF, Gentry WB, Schmitz ML. Transpleural subclavian central venous catheter placement in a child with scoliosis discovered during a thoracotomy. J Clin Anesth 2003; 15(2): 142-4. http://dx.doi.org/10.1016/S0952-8180(02)00517-2

[35] Anderson C, Graupman PC, Hall WA, Sweeny M, Lam CH. Pediatric intracranial complications of central venous catheter placement. Pediatr Neurosurg 2004; 40(1): 28-31. http://dx.doi.org/10.1159/000076574

[36] Chambers NA. Left internal jugular catheter tip wedged in the left superior intercostal vein, an inferior tributary of the brachiocephalic. Paediatr Anaesth 2005; 15(11): 1022-3. http://dx.doi.org/10.1111/j.1460-9592.2005.01707.x

[37] Costa S, De Carolis MP, Savarese I, Manzoni C, Lacerenza S, *et al*. An unusual complication of umbilical catheterisation. Eur J Pediatr 2008; 167(12): 1467-9. http://dx.doi.org/10.1007/s00431-008-0691-4

[38] Yiğiter M, Arda IS, Hiçsönmez A. Hepatic laceration because of malpositioning of the umbilical vein catheter: case report and literature review. J Pediatr Surg 2008; 43(5): E39-41. http://dx.doi.org/10.1016/j.jpedsurg.2008.01.018

[39] Chhabra A, Pawar DK, Khanna P, Sokhal N. Intraoperative dislodgement of an internal jugular central line with an undisturbed skin fixation. Paediatr Anaesth 2008; 18(11): 1130-1. http://dx.doi.org/10.1111/j.1460-9592.2008.02640.x

[40] Skinner TA, Mather SJ. Inadvertent extradural insertion of an internal jugular catheter in an infant. Br J Anaesth 1995; 75(6): 790-3. http://dx.doi.org/10.1093/bja/75.6.790

[41] Miyamoto Y, Kinouchi K, Hiramatsu K, Kitamura S. Cervical dural puncture in a neonate: a rare complication of internal jugular venipuncture. Anesthesiology 1996; 84(5): 1239-42. http://dx.doi.org/10.1097/00000542-199605000-00028

[42] Zenker M, Rupprecht T, Hofbeck M, Schmiedl N, Vetter V, *et al*. Paravertebral and intraspinal malposition of transfemoral central venous catheters in newborns. J Pediatr 2000; 136(6): 837-40.

[43] Vidwans A, Neumann DP, Hussain N, Rosenkrantz T, Sanders MR. Diagnosis and management of spinal epidural space extravasation complicating percutaneous central venous line placement in a premature infant: case report and review of literature. Conn Med 2000; 64(2): 79-82.

[44] Fujita Y, Sobue K, Hattori T, Takeuchi A, Tsuda T, *et al*. Inadvertent intrathecal cannulation in an infant, demonstrated by three-dimensional computed tomography: a rare complication of internal jugular vein catheterization. J Anesth 2006; 20(2): 122-5. http://dx.doi.org/10.1007/s00540-005-0383-4

[45] Skeehan TM. Unusual central venous catheter placement in a patient with congenital heart disease. J Cardiothorac Vasc Anesth 1993; 7(2): 204-6. http://dx.doi.org/10.1016/1053-0770(93)90219-B

[46] Cupitt JM. An unusual complication of a central venous catheter in a neonate. Paediatr Anaesth 2000; 10(6): 665-8.

[47] Eulmesekian PG, Pérez A, Minces PG, Lobos P, Moldes J, *et al*. Internal mammary artery injury after central venous catheterization. Pediatr Crit Care Med 2007; 8(5): 489-91. http://dx.doi.org/10.1097/01.PCC.0000282850.25806.0A

[48] Koklu E, Poyrazoglu H, Yikilmaz A, Canpolat M, Konuskan B. Subclavian artery pseudoaneurysm: a rare and serious complication of central venous catheterization in an infant. Pediatr Radiol 2008; 38(2): 220-3. http://dx.doi.org/10.1007/s00247-007-0630-y

[49] Chan CC, Lee V, Chu W, Tam YH, Li CK, *et al*. Carotid jugular arteriovenous fistula: an unusual complication of internal jugular vein catheterization in children. Pediatr Blood Cancer 2012; 59(7): 1302-4. http://dx.doi.org/10.1002/pbc.24137

[50] Kayashima K, Habe K. A case report of an accidental vertebral arterial puncture videotaped during central venous catheterization in a child undergoing a ventricular septal defect repair. Paediatr Anaesth 2012; 22(3): 311-2. http://dx.doi.org/10.1111/j.1460-9592.2011.03790.x

[51] Kayashima K. An accidental puncture of a small artery behind the internal jugular vein in real-time ultrasound-guided pediatric central venous cannulation. Masui 2013; 62(2): 193-6.

[52] Lovell M, Baines D. Fatal complication from central venous cannulation in a paediatric liver transplant patient. Paediatr Anaesth 2000; 10(6): 661-4. http://dx.doi.org/10.1111/j.1460-9592.2000.00576.x

[53] Hohlrieder M, Oberhammer R, Lorenz IH, Margreiter J, Kühbacher G, *et al*. Life-threatening mediastinal hematoma caused by extravascular infusion through a triple-lumen central venous catheter. Anesth Analg 2004; 99(1): 31-5. http://dx.doi.org/10.1213/01.ANE.0000117148.40842.CA

[54] Waddington MS, Mullins GC. Early complication of pediatric central venous cannulation. Paediatr Anaesth 2005; 15(11): 1001-5. http://dx.doi.org/10.1111/j.1460-9592.2004.01560.x

[55] Lu WH, Huang TC, Pan JY, Wang HP, Lin CC, *et al*. A potentially fatal complication during subclavian vein catheterization in an infant with congenital heart disease-puncture to pulmonary artery directly: a case report. J Clin Anesth 2008; 20(3): 225-7. http://dx.doi.org/10.1016/j.jclinane.2007.10.012

[56] Kurekci E, Kaye R, Koehler M. Chylothorax and chylopericardium: a complication of a central venous catheter. J Pediatr 1998; 132(6): 1064-6. http://dx.doi.org/10.1016/S0022-3476(98)70414-7

[57] Alkayed K, Plautz G, Gowans K, Rosenthal G, Soldes O, *et al*. Chylopericardium and chylothorax: unusual mechanical complications of central venous catheters. Pediatr Int 2013; 55(2): e4-6. http://dx.doi.org/10.1111/j.1442-200X.2012.03701.x

[58] Mupanemunda RH, Mackanjee HR. A life-threatening complication of percutaneous central venous catheters in neonates. Am J Dis Child 1992; 146(12): 1414-5.

[59] Wang CC, Chen YW, Wu ET, Chien YH, Hwu WL, *et al*. Identification and management of cardiac perforation from a double lumen catheter in an infant. Paediatr Anaesth 2007; 17(5): 500-1. http://dx.doi.org/10.1111/j.1460-9592.2006.02142.x

[60] Puvabanditsin S, Garrow E, Weerasethsiri R, Patel N, Davis SE, *et al*. Fracture of a Broviac catheter in a low-birth-weight infant. Hong Kong Med J 2008; 14(5): 411-3.

[61] Tutar E, Aypar E, Atalay S, Yavuz G, Doğu F. Percutaneous transcatheter retrieval of intracardiac central venous catheter fragments in two infants using Amplatz Goose Neck snare. Turk J Pediatr 2009; 51(5): 519-23.

[62] Jiang ZM, Chen ZH, Zhong JF, Hu SY, Wu BY, *et al*. One case of guide wire fracture and retention in child's internal jugular vein puncture. Chin Med J (Engl) 2012; 125(16): 2959-60.

[63] Giretti R, Caruselli M, Zannini R, de Vivo E, Piattellini G, *et al*. Dislocation of central venous catheters in paediatric patients. J Vasc Access 2006; 7(3): 132-5.

[64] Nuss R, Cole L, Le T, Orsini E, Harned R. Pinch-off syndrome in patients with sickle cell disease receiving erythrocytapheresis. Pediatr Blood Cancer 2008; 50(2): 354-6. http://dx.doi.org/10.1002/pbc.21058

[65] Caruselli M, Zannini R, Giretti R, Piattellini G, Bechi P, *et al*. The pinch-off syndrome in a pediatric patient. Paediatr Anaesth 2009; 19(3): 179-81. http://dx.doi.org/10.1111/j.1460-9592.2008.02689.x

[66] Eryilmaz E, Canpolat C, Celiker A. Catheter fragment embolization: a rare yet serious complication of catheter use in pediatric oncology. Turk J Pediatr 2012; 54(3): 294-7.

[67] Gowraiah V, Culham G, Chilvers MA, Yang CL. Embolization of a central venous catheter due to pinch-off syndrome. Acta Paediatr 2013; 102(2): e49-50. http://dx.doi.org/10.1111/apa.12085

[68] Keohane M, Allen R. Persistent atrial fibrillation following central venous cannulation. Paediatr Anaesth 1999; 9(2): 178-9. http://dx.doi.org/10.1046/j.1460-9592.1999.00359.x

[69] Cephus CE, Mott AR, Kertesz NJ, Slesnick TC. Transient complete atrioventricular block after placement of a central venous catheter in a neonate. Pediatr Crit Care Med 2007; 8(1): 64-6. http://dx.doi.org/10.1097/01.pcc.0000256618.78382.da

[70] da Silva PS, Waisberg J. Induction of life-threatening supraventricular tachycardia during central venous catheter placement: an unusual complication. J Pediatr Surg 2010; 45(8): E13-6.

[71] Ford S, Lauder G. Case report of Horner's syndrome complicating internal jugular venous cannulation in a child. Paediatr Anaesth 2007; 17(4): 396-8. http://dx.doi.org/10.1111/j.1460-9592.2006.02107.x

[72] Weil BR, Ladd AP, Yoder K. Pericardial effusion and cardiac tamponade associated with central venous catheters in children: an uncommon but serious and treatable condition. J Pediatr Surg 2010; 45(8): 1687-92. http://dx.doi.org/10.1016/j.jpedsurg.2009.11.006

[73] Food and drug administration. Cardiac perforation and tamponade: The deadly duo of central venous catheter. FDA patient safety news: Show #1, February 2002. http://www.accessdata.fda.gov/psn/printer.cfm?id=119. (accessed, 28 August, 2013)

[74] Nash P. Umbilical catheters, placement, and complication management. J Infus Nurs 2006; 29(6): 346-52. http://dx.doi.org/10.1097/00129804-200611000-00005

[75] Yoon SZ, Shin JH, Hahn S, Oh AY, Kim HS, *et al*. Usefulness of the carina as a radiographic landmark for central venous catheter placement in paediatric patients. Br J Anaesth 2005; 95(4): 514-7. http://dx.doi.org/10.1093/bja/aei199

[76] Inagawa G, Ka K, Tanaka Y, Kato K, Tanaka M, *et al*. The carina is not a landmark for central venous catheter placement in neonates. Paediatr Anaesth 2007; 17(10): 968-71. http://dx.doi.org/10.1111/j.1460-9592.2007.02258.x

[77] Nowlen TT, Rosenthal GL, Johnson GL, Tom DJ, Vargo TA. Pericardial effusion and tamponade in infants with central catheters. Pediatrics 2002; 110(1): 137-42. http://dx.doi.org/10.1542/peds.110.1.137

[78] Tsui BC, Richards GJ, Van Aerde J. Umbilical vein catheterization under electrocardiogram guidance. Paediatr Anaesth 2005; 15(4): 297-300. http://dx.doi.org/10.1111/j.1460-9592.2005.01433.x

[79] Meola S, Galante D. The use of ultrasound guidance to avoid the pinch-off syndrome. Paediatr Anaesth 2009; 19(6): 631. http://dx.doi.org/10.1111/j.1460-9592.2009.03007.x

[80] Knyazer B, Levy J, Rosenberg E, Lifshitz T, Lazar I. Horner's syndrome in an infant with complicated pneumonia. Isr Med Assoc J 2011; 13(8): 504-6.

[81] Lazar I, Cavari Y, Rosenberg E, Knyazer B. Horner's syndrome in patients admitted to the paediatric intensive care unit: epidemiology, diagnosis and clinical practice. Anaesth Intensive Care 2013; 41(1): 20-3.

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