Mechanical complications of central venous catheterisation in trauma patients

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ABSTRACT

INTRODUCTION Central venous catheterisation (CVC) is a commonly performed procedure in a wide variety of hospital settings and is associated with appreciable morbidity. There is a paucity of literature focusing on mechanical complications specifically in the trauma setting. The aim of our study was to determine the spectrum of mechanical complications in a high-volume trauma centre in a developing world setting where ultrasound guidance was not available.

METHODS A retrospective study was performed analysing data from a four-year period at the Pietermaritzburg Metropolitan Trauma Service in South Africa.

RESULTS A total of 178 mechanical complications (18%) occurred in 1,015 patients undergoing CVC: 117 pneumothoraces, 25 malpositions, 18 catheter dislodgements, 14 arterial cannulations, one air embolism, one chylothorax, one pleural cannulation and one retained guide-wire. The internal jugular vein (IJV) approach was associated with a higher overall complication rate than the subclavian vein (SCV) approach (24% vs. 13%, $p < 0.001$). Pneumothorax (73% vs. 57%, $p < 0.001$) and arterial cannulation (15% vs. 0%, $p < 0.001$) were more common with the IJV. Catheter dislodgement (21% vs. 0%, $p < 0.001$) was more common with the SCV. Junior doctors performed 66% of the CVCs and this was associated with a significantly higher complication rate (20% vs. 12%, $p < 0.001$).

CONCLUSIONS CVC carries appreciable morbidity, with pneumothorax being the most frequent mechanical complication. The SCV was the most commonly used approach at our institution. The majority of CVCs were performed by junior doctors and this was associated with a considerable complication rate.

KEYWORDS

Trauma – Central venous line – Mechanical complications

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Central venous catheterisation (CVC) is a procedure which is frequently performed in the trauma setting.¹ In the United States alone, over five million procedures are performed each year.² However, it is a procedure associated with appreciable morbidity. Complications occur in up to 15% of all patients,^{1–5} with mechanical and infective complications being the most commonly encountered. Most literature regarding CVC-related complications originates from anaesthesia and critical care settings.⁴ The incidence of mechanical complications specifically related to CVC in the trauma population is much less well documented.¹ Very little is known about the incidence and spectrum of these complications in South Africa. The objective of this study was to review the incidence of mechanical complications associated with CVC in a high-volume trauma centre in South Africa.

Methods

This study was undertaken at the Pietermaritzburg Metropolitan Trauma Service (PMTS). A retrospective review of a

prospectively maintained regional trauma registry was conducted over a four-year period from January 2010 to December 2013. Ethics approval was granted by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal. The PMTS provides definitive trauma care to the city of Pietermaritzburg and the western part of the KwaZulu-Natal province. It also serves as the trauma referral service for 19 other district hospitals, with a total catchment population of over three million.

All patients who underwent CVC in the trauma resuscitation room were eligible for inclusion in the study. Patients in whom CVCs were performed in the operating room or intensive care unit were excluded, as well as those who had a central venous catheter *in situ* prior to arrival at our trauma centre. Patients with an underlying haemothorax or pneumothorax and those who underwent resuscitative thoracotomy were also excluded. Only central venous catheters inserted via the subclavian vein (SCV) or the internal jugular vein (IJV) were considered in this study.

Central venous catheterisation procedure

The central venous catheter used at our institution is the triple lumen Arrow® catheter (Arrow International, Reading, PA, US). The insertion method closely follows *Advanced Trauma Life Support*® (ATLS®) teachings,⁶ using the Seldinger technique. At the time of the study, all CVCs at our institution were performed using the anatomical landmark technique without the use of ultrasound guidance. For the IJV approach, the anatomical landmark was defined by Sedillot's triangle, bounded by the sternal head of the sternocleidomastoid muscle medially, the clavicular head of the sternocleidomastoid laterally and the superior border of the medial third of the clavicle inferiorly.⁵ This is also often described as the 'high approach' and is the preferred option at our institution. For the SCV approach, the anatomical landmark was defined as 1cm below the junction of the middle and medial third of the clavicle.⁵

A mechanical complication was defined as any immediate mechanical complication that occurred following CVC. As per ATLS® protocol, all patients who had CVC inserted in the trauma resuscitation room underwent a chest X-ray as soon as practically possible.⁶ Immediate mechanical complications were classified as follows: pneumothorax, malposition, catheter dislodgement, arterial cannulation, air embolism, chylothorax, pleural cannulation and retained guide-wire.

Catheter tip position

At our institution, the position of the central venous catheter tip that is considered acceptable is at the junction between the superior vena cava and the right atrium.⁵ This corresponds to the anterior part of the first intercostal space on chest X-ray, which defines the beginning of the superior vena cava.⁷ Central venous catheter tips directed incorrectly were classified as malpositioned (e.g. a right SCV central venous catheter tip entering the right IJV with the tip directed superiorly). Central venous catheter tip positions that were grossly abnormal (e.g. in the right atrium or ventricle) were also included as malpositions. Figure 1 shows an example of an attempted CVC via the right SCV, with the catheter tip entering the left SCV. Dislodgement was defined as any central venous catheter that was inadequately secured resulting in dislodgement requiring reinsertion of a new one.

Operators

Operators were classified as junior or senior doctors, all of whom work exclusively in our trauma centre with general surgery as the primary specialty. A junior doctor was defined as any doctor within two years of graduation (PGY2) from medical school. A senior doctor was defined as any doctor above PGY2.

Statistical analysis

Data were analysed using Stata® version 13.0 (StataCorp, College Station, TX, US). Continuous variables were assessed with Student's t-test while differences in frequencies of categorical variables were assessed with either Pearson's chi-squared or Fisher's exact test (depending on cell numbers). A *p*-value of <0.05 was deemed statistically significant.

Figure 1 A central venous catheter inserted via the right subclavian vein with catheter tip in the left subclavian vein

Results

A total of 1,015 patients who underwent CVC in the trauma resuscitation room were eligible for inclusion in the study. Sixty-five per cent (660/1,015) were male and the mean age was 31 years (standard deviation: 11 years). A total of 623 CVCs (61%) were inserted via the SCV and the remaining 392 (39%) via the IJV approach. A total of 178 (18%) mechanical complications occurred in 1015 patients. These were as follows: 117 pneumothoraces, 25 malposition, 18 catheter dislodgement, 14 arterial cannulation, one air embolism, one chylothorax, one pleural cannulation and one retained guide-wire. This was summarised in Table 1.

Internal jugular vein vs. subclavian vein

Among the 623 CVCs performed via the SCV approach, there were mechanical complications in 84 cases (13%) while among the 392 CVCs performed via the IJV approach,

Table 1 Mechanical complications among 1,015 patients

Complications	<i>n</i>
Pneumothorax	117 (66%)
Malposition	25 (14%)
Dislodgement	18 (10%)
Arterial cannulation	14 (8%)
Air embolism	1 (1%)
Chylothorax	1 (1%)
Pleural cannulation	1 (1%)
Retained guide-wire	1 (1%)
Total	178 (100%)

complications occurred in 94 patients (24%). This difference was highly statistically significant ($p<0.001$). Pneumothorax (73% vs. 57%, $p<0.001$) and arterial cannulation (15% vs. 0%, $p<0.001$) were more common in the IJV approach whereas catheter dislodgement (21% vs. 0%, $p<0.001$) was more common in the SCV approach (Table 2).

Operator seniority

Of the total 1,015 patients who underwent CVCs, 673 (66%) were performed by junior doctors while the remaining 34% were by senior doctors. There was a significantly higher complication rate among the junior doctors (20% vs. 12%, $p<0.001$).

Discussion

CVC is one of the most commonly performed procedures in a wide variety of hospital settings and over five million central venous catheters are inserted in the US annually.² CVC is associated with considerable morbidity, with an overall complication rate of 15%.² Complications are usually classified as either mechanical or infective.² Mechanical complications, some of which are potentially fatal, have been reported in up to 29% of patients.^{2,8}

Most of the available literature describes complications across a wide range of specialties, most notably in anaesthesia and critical care settings.^{8,9} The incidence of mechanical complications in the trauma setting is less well documented.¹ Pappas *et al* from the US published the first series focusing exclusively on trauma patients undergoing resuscitation in 1992, with a complication rate of 7.8%.¹⁰ Two decades later, Ives *et al* reviewed 2,935 trauma patients at the Los Angeles County and University of Southern California Medical Center, and reported a much lower complication rate (1.5%).¹ The most common complication was pneumothorax, accounting for 64% of all complications. The findings from our study were consistent with this. However, not all patients had chest X-rays prior to the procedure to exclude a pneumothorax that may have been present before the CVC, which is a potential confounder that requires further study to clarify.

Over two-thirds of all central venous catheters in the study were inserted via the SCV approach, which is likely to be related to practicality of access to relevant regions for trauma patients (e.g. blunt trauma with cervical spine immobilisation). Malpositioning of the central venous catheter was found to be more common in the SCV approach. However, it should be noted that the optimal position of the central venous catheter tip remains highly controversial.¹¹ Due to the theoretical risk of arrhythmia, it is generally recommended that the catheter tip should be at the junction between the superior vena cava and the right atrium.⁵ Thoracic venous anatomy and the corresponding radiological correlations on chest X-ray were well described by Godwin and Chen.⁷ The anterior part of the first intercostal space corresponds to the beginning of the superior vena cava⁷ and was therefore used as a practical landmark in assessing central venous catheter tip position at our institution.

Table 2 Comparison of the internal jugular vein (IJV) and subclavian vein (SCV) approaches for each individual mechanical complication

Complication	IJV (n=94)	Complication rate	SCV (n=84)	Complication rate	p-value
Pneumothorax	69	73%	48	57%	<0.001
Malposition	7	7%	18	21%	0.269
Dislodgement	0	0%	18	21%	<0.001
Arterial cannulation	14	15%	0	0%	<0.001
Air embolism	1	1%	0	0%	0.386
Chylothorax	1	1%	0	0%	0.386
Pleural cannulation	1	1%	0	0%	0.386
Retained guide-wire	1	1%	0	0%	0.386

It was noted that the overall rate of mechanical complications differs considerably between the two approaches, with the IJV approach associated with significantly higher complication rates. This may reflect the relative experience of the operator as the SCV approach was much more commonly performed in the trauma setting.

Ultrasound guidance for CVC is increasingly being utilised and has become the standard of care in many developed countries. There is good evidence to suggest that ultrasound-guided CVC is associated with lower complication rates for the IJV approach.^{12–15} The National Institute of Clinical and Health Excellence (NICE) in the United Kingdom has recommended ultrasound guidance as the preferred method for insertion of central venous catheters into the internal jugular vein (IJV)¹². A study by Wigmore, *et al.* in London demonstrated a significant reduction in complication rates following implementation of the NICE guideline¹⁶. A recent Cochrane review by Brass *et al.* demonstrated that ultrasound guidance reduced the complication rate for the IJV approach, increased success rates and reduced the time taken to perform the procedure.¹⁵

Although the SCV approach remains more technically difficult, ultrasound guidance does offer small advantages in safety and quality when compared with the anatomical landmark technique.¹² Soni *et al* recently conducted a national survey in the US and noted that most intensivists routinely use ultrasound guidance for the IJV but not for the SCV.¹⁷

Our study also demonstrated that the majority of CVCs at our institution were performed by junior doctors. This invariably represents a heterogeneous group of operators who have different levels of training and experience. A previous study from our institution suggested that a considerable proportion of junior doctors did not possess sufficient anatomical knowledge with trauma procedures.¹⁸ The varying levels of supervision of these junior doctors may have contributed to the higher complication rates. Pneumothorax, malposition, catheter dislodgement and arterial cannulations were

the most common mechanical complications. Among these, catheter dislodgement (due to an inadequate fixation) was probably more likely related to technical error rather than a knowledge deficit.

Further studies are required to define the actual experience of these junior doctors and how their knowledge influences the complication rate. At present, we suggest that the introduction of ultrasound guidance, implementation of the procedure-specific protocol, coupled with supervised training of junior doctors may potentially improve the complication rates.

Conclusions

CVC carries appreciable morbidity, with pneumothorax being the most commonly encountered complication. The SCV is the most commonly used approach at our institution. The majority of CVCs were performed by junior doctors and this was associated with a considerable complication rate.

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