Title:

A systematic review of management of inadvertent arterial injury during central venous catheterisation.

Short Title:

Management of arterial injury during central line insertions

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Abstract

Introduction

Central venous catheterisation (CVC) is a technique commonly used to obtain vascular access and over five million CVC's are inserted annually. This systematic review of CVC related arterial injury aims to compare outcomes reported with different management strategies.

Methods

PRISMA guidelines were followed. A search of Medline, Embase, Central and CINAHL was performed. Results were limited to papers in humans and in English with duplicates removed. Details of cases including site and nature of arterial injury, use of ultrasound, methods for identifying arterial placement, management methods used and any reported outcomes were collated from all papers. Successful management was defined as control of haemorrhage without evidence of further complications.

Results

2,187 abstracts were screened and 78 full manuscripts were obtained and reviewed. 24 papers were of relevance and were included in this review. Amongst the papers, 80 cases of arterial injury were reported. Successful treatment by removal and compression, endovascular methods, and open surgical repair were 5.6%, 94.6% and 100%, respectively.

Discussion

Removal and compression of the arterial site is a poor management method and is associated with a high rate of complications. Endovascular approaches had a high rate of

success with advantages of endovascular techniques including access to arteries which are difficult to expose surgically and avoidance of general anaesthesia. Endovascular repair might be considered depending on site of injury or local expertise though surgical repair reported the best results in this review with no complications seen.

Key words: Systematic review, Central Venous Catheterization, Vascular Injuries

Introduction

Central venous catherterisation (CVC) is a technique commonly used as a way of obtaining vascular access in both the short and longer term. Around 200,000 CVC's are inserted annually in the National Health Service (NHS)(1) and more than five million CVC's are inserted in the United States annually(2) for various indications such as dialysis, invasive monitoring and drug or blood product administration.

Common sites for insertion of central venous catheters include the internal jugular, subclavian, and femoral veins. Failure rates of CVC insertion are reported to range from 3.7 to 12% (3, 4) and there are attendant risks presented by CVC insertion with arterial injury or cannulation being a particularly feared event with potentially fatal complications ranging from cerebral ischaemia to airway-threatening haematoma formation. There are currently no published guidelines on how to manage arterial injury occurring from attempted CVC insertion and no clear evidence to guide practice. Strategies for managing CVC insertion related arterial injury depend upon the extent of injury and range from simple removal of the catheter and firm compression to formal open surgical exploration with vessel repair (5). Less invasive management using endovascular techniques has been increasingly reported in the literature as the associated technology has advanced as have expertise(6). Endovascular techniques are considered especially useful for injuries to the subclavian artery which is not only difficult to compress but also difficult to access surgically, especially in more medial injuries (7).

Previous algorithms for management of arterial injury have been suggested (5), though these lack inclusion of evidence for endovascular management. The objective of this

systematic review of the current literature relating to the management of CVC related arterial injury was to compare outcomes reported with different management strategies.

Methods

PRISMA guidelines were used to inform the protocol and reporting of this study.

Search strategy

A search of Medline, Embase, Central and CINAHL from 1946 to September 2015 was performed. The search included the following terms:

central venous AND (catheter or cannula) AND (Carotid OR Arter* OR Complicat* OR Injur*).

Results were limited to papers in humans and in English with duplicate articles removed.

Inclusion criteria

Titles and abstracts were manually screened (OD and GS) for relevance and full texts of any reports appearing to contain details of arterial injury in CVC insertion were retrieved. References of full texts were hand searched for further reports of relevance.

Data extraction

Details of cases including use of ultrasound (US) guidance, the nature and site of arterial injury, methods of identifying the arterial injury, management employed and any reported outcomes were collated for inclusion in this review. The extent of injury was also recorded and these were categorised into two groups - needle and guidewire injury to artery only; and introducer sheath or catheter insertion into artery.

Outcomes

Successful management of the arterial injury was defined as removal of CVC components and control of haemorrhage without evidence of further complications. Length of follow up was poorly reported so no minimum follow up period was stipulated Any descriptions of employing more than one management strategy in a single patient were counted as two events (i.e. failed compression leading to surgical exploration in the same subject).

Results

Literature Search

Results of the literature search and the inclusion and exclusion process are summarised in figure 1. 78 full texts were retrieved of which 24 were of relevance (4-6, 8-28).

Injuries reported

Sites of arterial injury were categorised into three groups - carotid, subclavian and other with frequencies of 51, 24 and 5 cases respectively. Other reported sites of injury included the descending thoracic aorta, vertebral artery, axillary branch and the thyroid artery. Four of the injuries were needle or guidewire puncture only and seventy six involved the dilator or catheter being passed into the artery. Of the 80 arterial injuries, the majority occurred during surface anatomy guided cannulation without US guidance, however in 8 (10%) of cases the injury occurred despite the documented the use of ultrasound guidance during cannulation.

Identification of injury and interventions

Methods for identification of injuries are summarised in table 1. A number of arterial injuries were identified and confirmed through more than one method and these were grouped together as ‘various methods’ (e.g. pulsatile flow noted and then arterial cannulation confirmed on imaging). The method for identification of injury was not reported in 37 cases.

Management and Complications

Management methods employed for each case of arterial injury are summarised in table 2 with complications encountered and success rates of each management method given as a percentage. There were 37 reports of managing an arterial injury via an endovascular approach. Endovascular repair methods in included reports ranged from balloon tamponade or coil embolisation, to covered stent insertion and the use of a variety of percutaneous closure devices. The 2 reported cases of complications which occurred with endovascular approaches included failure to arrest haemorrhage and an embolic stroke.

Discussion

CVC insertion is commonplace in clinical practice and mechanical complications of insertion may include pneumothorax, air embolism, misplacement and bleeding. Arterial injuries are perhaps the most feared complication and can easily result in catastrophic morbidity and mortality if not promptly and appropriately managed.

Prevention of arterial injury is of utmost importance and the use of US guidance during CVC insertion should now be considered routine due to reduced risk of arterial cannulation and increased rate of successful CVC insertion (1, 29). However, 10% (8/80) of cases in this review had documented that the procedure was performed under US guidance and still resulted in an arterial injury. At present in the UK, there is no defined level of training or skill/experience that is required or thought to be required for the use of US guidance to improve outcomes in CVC placement. The American College of Emergency Physicians has attempted to address this issue by providing recommendations that clinicians should undergo basic ultrasound training (1-2 days) followed by a minimum of 25 documented

and reviewed procedures before independent use (30). Other factors related to the successful insertion include: placement of CVC in an emergency and inserting a CVC into the left internal jugular vein (31). Insertion of a CVC into the right internal jugular vein (IJV) is potentially more likely to succeed as the right IJV may have a wider diameter, and lie more superficially than the left as well as offering the most direct route to the superior vena cava (32).

Following insertion of the CVC, the correct position of the catheter tip must be evaluated. Performing post-insertion US, observing blood colour, measuring intra-luminal pressure, and waveform type and checking the oxygen saturation can all aid the confirmation of the CVC position and allow early identification of inadvertent arterial misplacement (33). Arterial CVC position was identified in included cases by several methods including pulsatile flow from the CVC port, arterial pressure and waveforms transduced through the catheter and visible haematoma formation or haemorrhage. Early identification helps to reduce the risk and severity of severe complications.

The incidence of arterial needle puncture as part of CVC placement may occur in 3.7 to 12% (3, 4) of cases but is frequently recognised and managed with compression. More significant arterial injury involving the dilator or catheter is reported in 0.1% to 1.0% of attempted CVC placements (34). Resultant complications in the included cases were wide ranging and included haematoma and excessive bleeding, arteriovenous fistula, haemothorax, pseudoaneurysm, thrombus formation resulting in stroke, respiratory failure and death (5, 6, 19, 27). In these included cases arterial injury managed by removing the needle or catheter from the artery and applying pressure to the insertion site frequently led to complications. 94.4% of injuries managed by compression resulted in complications, notably haematoma formation and haemorrhage and led to 3 deaths due to embolic

stroke. There were only 2 complications with endovascular management though both were of a highly significant nature including failure to arrest haemorrhage and an embolic stroke. There did not seem to be any evidence of increased complication due to any particular endovascular repair method employed.

Surgery appears to be the optimal method when managing arterial injury during CVC insertion with no reported complications occurring in any of the cases in this review. Surgery is more invasive and may carry more morbidity due to the open nature of repair compared to endovascular methods and may be less favourable in subclavian artery injury as this area is more difficult to expose in open surgery. Other potential disadvantages to surgery including the risks of a general anaesthetic in a critically unwell patient.

Discretion is needed in each case to decide on the most appropriate way of dealing with inadvertent catheter-related injury. Both the extent of the arterial injury, (i.e. needle/guidewire or introducer/catheter) and time taken for arterial injury to be recognised need to be taken into account when deciding on how best to manage the injury. Operative management has been recommended if the injury is recognised greater than 4 hours after cannulation (35). If only the needle or guidewire punctures the artery, complications are still possible. The cases in this review with only needle or guidewire arterial injury still suffered serious complications such as arteriovenous fistula, hemiparesis and haematoma formation causing airway obstruction (11, 15, 25). However, many needle only injuries are likely to be managed successfully by removal and compression and will not generate complications that might prompt publication of a case report. Management of needle and guidewire injuries by removal and compression may be considered if the arterial injury is noticed immediately and the artery can be easily compressed to control any bleeding. Removal and compression does appear to carry a significant risk of complications with

dilator or catheter arterial injury and so should not be considered. Although device diameter was not always reported in the included cases, it is likely that larger catheters may have increased complication rates when an artery is inadvertently punctured (5).

Based on the results of this literature review, open surgery should be considered the optimum treatment in managing arterial cannulation with a CVC in patients who are fit for general anaesthesia. However, consideration of individual patient situations will always be required. Individuals may present with significant haematoma which would mandate a surgical evacuation, whilst other patients may be acutely unwell or will have other morbidities making the endovascular advantages of minimal invasiveness and avoidance of a general anesthetic attractive. Endovascular management was only marginally less successful in this review and may also be more appropriate if the injury involves the medial subclavian artery as this may be difficult to access surgically (36). Diameter of the CVC device and the concurrent anticoagulation status of patients must also be considered when determining the most appropriate management option.

It was evident amongst cases in this review that patients suffered fewer complications and generally had a better outcome if the guidewire/dilator/catheter was left in situ in the artery whilst management preparations were made and the patient had been transferred to the endovascular or operating theatre, which is in keeping with previous consensus on management of these injuries(37).

Thrombus formation at the site of arterial injury with embolisation at the time of catheter removal might be avoided by the use of systemic anticoagulation. In this review as 8 out of 18 (44%) of cases managed by removal and compression were complicated by the occurrence of stroke or thrombus formation. Anticoagulation of patients following an arterial injury or cannulation was recommended in the experience of Bechara et al (10), although prophylactic anticoagulation following arterial cannulation was not documented in

any of the included cases. With regard anticoagulation, consideration must be given to the timing of the injury and the predicted time to repair, as protective effects against thrombosis at the injury site must be balanced to the risk of exaserbating any bleeding during device removal..

Limitations

There is expected to be a significant degree of publication bias amongst the papers identified for this review. The published cases are of significant complications arising from inadvertent arterial injury and there were few reported needle and guidewire only injuries. The overwhelming majority of inadvertent needle and guidewire arterial injuries are likely to be managed successfully by compression and are therefore unlikely to appear in published literature and any conclusions drawn in this review must be interpreted in light of this probable bias.

Conclusion

We have constructed a possible algorithm based on the evidence collated in this review and on previously proposed algorithms for management of arterial cannulation [figure 2], though it is important to note the lack of high level evidence to support any of the treatment options discussed in this review. Surgery or endovascular repair might equally be considered first line depending on the site of arterial injury or local expertise. Open surgery had no complications but endovascular cases saw a high technical success rate with advantages of their minimally invasive nature and avoidance of need for general anaesthesia. Surgery should be the preferred option if there is no endovascular treatment service.

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Table 1 – Method by which arterial cannulation identified

How injury identified	**Number of cases**
Pulsatile flow	12
Arterial pressure/waveform transduced through catheter	4
Blood gas analysis	6
Haemorrhage/haematoma/swelling/pain	5
Imaging	3
Murmur/thrill	1
During surgery	1
Various methods	11
Not reported	37

Table 2 - Management methods employed and success rate

	Removal and Compression	**Endovascular**	**Surgery**
No complications (n=)	1	35	37
Complications (n=)	17	2	0
Complication types	5-failure to control haemorrhage 1-haemothorax 1-left lung collapse 1-pseudoanuerysm 4-embolic stroke 2-arteriovenous fistula 3-death	1- failure to control haemorrhage 1- cerebral embolus	None
Success rate (%)	5.6	94.6	100.0

Figure 1 – PRISMA diagram summary of literature search and report inclusion/exclusion process.

Figure 2. Suggested algorithm for management of arterial injury during CVC insertion.