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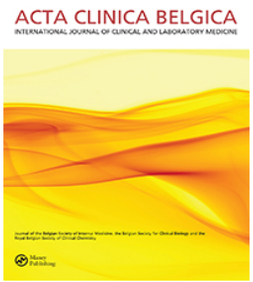

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Overlooked guide wire: a multicomplicated Swiss Cheese Model example. Analysis of a case and review of the literature

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ABSTRACT

Objectives: Central venous catheter (CVC) implementation is now usual in emergency department. The most common complications are misplacement, bleeding, pleural perforation, thrombosis and sepsis. Forgetting a guide wire in the patient's body after catheterization is an underestimated complication of this procedure; only 76 cases are described. Even if the majority of patients remained asymptomatic, severe complications can happened even years later. This article's aim is to identify the sequence of elements that led to the event occurrence and to suggest recommendations of good practice to minimize complications related to central catheter placement.

Method: After reviewing all the complications related to central venous catheterization and their frequencies, we analyse from a case report and a review of the literature the sequence of elements that led to the medical error. We use an Ishikawa diagram to show our results and the links between them.

Results: Our Ishikawa diagram shows that material, human resources, procedural and radiological involvement factors are the main elements on which we can act to reduce the complications rate after central venous catheterization. We advocate for the establishment of standardized procedures before, during and after the technical gesture.

Conclusions: Because of human nature, errors will always be possible when taking care of a patient. However, we propose good practice recommendations to avoid the repetition of a forgetting guide wire after central venous catheterization.

KEYWORDS

Central catheter; emergency department; patient safety; human error; incident reporting; checklist

Introduction

Central venous catheter (CVC) implementation has become common practice in emergency units. The most used technique was first described by Seldinger in 1953 [1]. More than 5 million of these catheters are placed every year in the United States [2] and more than 10 million in the world [3]. They are mainly used for instable patients but also for over 25% of the hospitalized patients worldwide [4].

The main indications for the use of CVC are [5] inaccessible peripheral veins, need for high-fluid debit delivery, drugs administration and need for intensive hemodynamic monitoring.

Like every invasive method, CVC implementation involves some risks [6]. The complication rate can be as high as 12%. The most common complications are catheter mispositioning, bleeding, pleural perforation, venous thrombosis and sepsis.

A rare but serious complication is the migration and the guide-wire loss inside the patient's venous system. More than 50 cases have been reported in the literature [7]. This article's aim is to analyse, and find in clinical situations, all the elements that led to the event occurrence in order to make good practice recommendations to prevent the occurrence of this complication and finally improve the quality of care.

Case report

A 44-year-old woman arrived at the emergency department (ED) with a history of pain and oedema on the left arm. She was treated for non-insulin-dependent diabetes mellitus, high blood pressure, polycystic ovary syndrome and hypothyroidism.

The patient declared that oedemas were also sometimes present on her legs. She noted an increase in her abdominal perimeter and a weight gain during the last month. The blood test was normal except for the high value of D dimer. An US Doppler of the arm was performed but it did not show any vascular anomaly; a local thrombosis was excluded. Then, thorax and abdomen CT scan were ordered to find the oedema aetiology. They showed an extended thrombosis from the brachiocephalic vein to the superior cava vein. It also showed a probe in the vessels extending from the cava to the iliac vein (Figure 1). A chest X-ray was ordered; it confirmed the presence of a guide wire in the cava vein (Figure 2).

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Figure 1. The guide wire is clearly visible on this abdominal CT scan performed 10 years after the CVC placement.

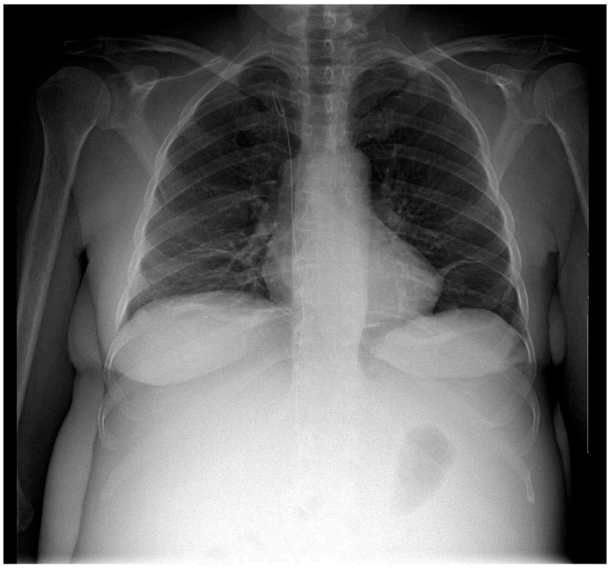

Figure 2. The upper extremity of the radio opaque guide wire positioned in the vena cava visible on standard chest radiography.

Her medical past review revealed morbid obesity. She had undergone a bypass surgery 10 years earlier. During the procedure, a CVC was placed. A chest radiograph was performed and showed the retained guide wire. The attending radiologist noted the catheter's good positioning but also an overlapping material in the para vertebral area.

In the post-surgery period, the patient presented fever and an increase in C reactive protein in blood test. Chest X-ray and abdominal CT scan were performed. The radiologist described a small collection around the surgery area but did not notice the guide wire.

During the decade between the CVC placement and the symptom appearance, the patient underwent four thorax X-rays, eight upper gastrointestinal swallow radiographs, two abdominal CT scans and one coronarography. She also had three other surgeries (abdominoplasty, cholecystectomy and resection of marginal ulcer). Radiologists described the guide wire in 50% of the chest X-rays, 25% of the upper gastrointestinal swallow radiographs and 0% of the CT scans.

The patient is now treated by anticoagulant. Two attempts to withdraw the guide wire remained unsuccessful because of its complete incorporation to the vessel wall. The complete medical check-up concluded that she had cirrhosis Child–Pugh B7 with oesophageal varicose veins, portal hypertension and ascites secondary to non-alcoholic steatohepatitis. No hepatic vein thrombosis was found in the proceeded imageries; so, a Budd–Chiari syndrome cannot be mentioned despite the fact that major part of the blood flow was drained by the Azygos veins.

In conclusion, the thrombosis and guide-wire role in the patient's liver pathology remain unclear.

Discussion

There are several complications related to CVC. After reviewing all these complications and their frequencies, we analysed, with the perspective to improve safety and quality, the involved elements that lead to the adverse effect occurrence described above. To do this, we chose to use the Ishikawa diagram. After this analysis, we suggest good practice recommendations to minimize complications related to central catheter placement.

Central venous catheterization complications

Large numbers of central venous catheterizations are performed each year in the EDs around the world. This number is likely to increase every year. As in any invasive procedure, complications are observed in the immediate or delayed post-procedure period. Those main complications are summarized in Table 1.

Immediate complications

Misplacement

There are three catheter misplacement types: intravenous misplacement, arterial misplacement and extravascular misplacement. The ideal catheter tip position is a central vein outside of the pericardial sac and parallel to the long axis of the vein [9]. The rate of catheter misplacement depends on the insertion site. The complication rate is greater with, in descending order, the left internal jugular vein, the right subclavian, the left subclavian and the right internal jugular. It is probably due to the vein length, the oblique course to the heart and the local tributaries [10]. A misplaced catheter can lead to vessel walls

Table 1. Summary of the main complications of central venous catheterization and structural proceedings to minimized risks.

Immediate	Rate (%)	Improving care-quality-proposed procedures	Rate reduction by using ultrasound [8]
Arterial puncture	1–10	Connect to a pressure transducer to assess for venous waveforms Preferentially choose the subclavian approach	10.6–1%
Bleeding	0.5–1.6	Check platelet count and INR Use the right size of catheter	8.4–.4%
Pneumothorax	0.5	Avoid anatomic region with previous operations, trauma or radiotherapy Preferentially choose the internal jugular approach Be careful with obese patients	2.4–0%
Delayed	**Rate (%)**	**Improving care-quality-proposed procedures**	**Rate reduction by using ultrasound [8]**
Sepsis	3–8	Sterile-barrier precautions (mask, cap, sterile gown, sterile gloves) Use of skin antiseptic solutions Effective and prolonged hand cleaning Choose the subclavian site: more frequent infectious complications are described when using femoral or internal jugular access	16–10.4%
Thrombosis	1–5	Remove unnecessary central lines immediately Check for thrombophilia or acquired hypercoagulability Remove unnecessary central lines immediately Use single lumen rather than multi-lumen catheter Preferentially choose the subclavian approach	
Missed guide wired	76	cases	

INR: International normalized ratio.

perforation, retrograde injection, local venous thrombosis or catheter dysfunction.

Arterial puncture is the most common complication during central venous catheterization with a described rate of 1–11% [11]. Arterial cannulation can be recognized by the blood flow colour and pulsatility. A pressure transducer monitoring can be used to confirm misplacement. Complications related to arterial puncture are haematoma, false aneurysm with local compression (such as airways), arterial dissection and thromboembolism with distal ischemic damage.

Another catheter misplacement type is when the tip is outside the vein. A lot of different anatomical positions can be found in the literature, such as pericardium, pleural space, mediastinum, extradural space with complications such as tamponade, haemothorax and mediastinal compression.

Real-time ultrasound-guided catheterization can reduce the total rate of complications (13–4.0%) and increase the success rate (97.6–87.6%) compared with conventional landmark techniques [12].

Bleeding

Bleeding complications are reported in 0.5–1.6% of the cases [13]. In most cases, a simple compression of the haematoma is sufficient to stop the bleeding. However, patient haemostatic anomalies can increase the bleeding risk. Platelet count <50,000/ml or an international normalized ratio >2 has been shown to confer a small absolute risk of bleeding of approximately 5%. Precautions must be taken with those patients [14].

Pleural perforation

Pleural perforation is a rare complication of CVC placement. Some studies report an overall rate of 0.5% [15]. Risk factors for iatrogenic pneumothorax are the use of the jugular access instead of the subclavian access, a positive pressure ventilated patient and an unsuccessful first vein site cannulation.

Delayed complications

Thrombosis

Thromboses related to venous catheterization are explained by vessel wall damage and reduction of blood flow around the catheter (up to 60%) [4]. Classical risk factors of thrombosis like malignancy or thrombophilia can increase the occurrence. The presence of IV catheter is the most common cause of upper extremity deep venous thrombosis [16]. In most cases, the venous thrombosis remains subclinical but sometimes symptoms like arm or neck pain can be observed. Pulmonary embolism (PE) can also complicate a subclinical catheter-related thrombosis but there is no evidence of any association with CVC in seriously ill patients.

Sepsis

Infection is the main complication of catheter in critically ill patients. The occurrence of bloodstream infections goes up from 3% to 8% with a range of mortality rate from 0% to 35% [17]. These infections independently increase hospital costs and length of stay but have not been shown to independently increase mortality [18].

Coagulase-negative staphylococci are the most common microorganisms associated with catheter-related bloodstream infections. In short-term catheter (<15 days), there is a colonization of the catheter tip due to skin bacteria migration from the insertion site. In long-term catheter (>15 days), the colonization is due to manipulation of the venous line with bacteria migration in the internal lumen.

Overseen guide wires

The most used technique to place a CVC is the Seldinger technique. It involves the use of a guide wire that can be forgotten in the patient central vessel. This omission can be called a never event, a serious but preventable error in medical care that should never occur if healthcare workers implemented the relevant preventive measures [19]. A recent analysis of published case reports made by Pokharel and colleagues found 76 described cases [7]. The occurrence of this complication is probably underestimated because all cases are not systematically reported. In most cases (75%), the patients remain asymptomatic. In the symptomatic quarter of patients, some present short-term complications (retroperitoneal haematoma, gall bladder perforation and thrombosis) and other delayed complications (ventricular perforation, cardiac tamponade, palpitation, PE, endocarditis and sepsis).

Analysis of the incident's origin using the Ishikawa diagram

The oversight of a guide wire can be categorized as medical error that cannot be imputed to only one person or one forgotten manipulation. It is always an accumulation of oversights and failures; it is the consequence of the entire system failure. These error accumulations were modelled by James Reasons in a Swiss Cheese Model [20]. In this model, the organized defences against failures are modelled as a series of barriers, represented as the slices of a cheese. The holes in the slices represent weaknesses in the system. The system produces failures when a hole in each slice momentarily aligns, allowing 'a trajectory of accident opportunity' to arise, so that a hazard passes through holes in all the slices, leading to a failure. Here, we want to analyse the origins of the incident using an Ishikawa diagram. This method is used to individualize the elements that lead to the error and the links between them.

Human resources

We know that approximately 98,000 people have died each year as a result of medical errors in America [21]. First published by the Institute of Medicine in the publication 'To err is human' in 1998, this number had been recently updated by Makary and Daniel from Johns Hopkins University of School of Medicine (Baltimore) [22]. With some new criteria, their estimates suggest now a range of 210,000–400,000 deaths a year among patients in the United States. However, the situation is worst for patient safety because these estimates consider only deaths and not injuries, disabilities, complications and so on.

Improving healthcare quality necessarily induces human resource analysis but constantly keeping in mind that the problem is about good people working in bad systems that need to be made safer.

In our case report, the CVC has been placed by an anaesthesiologist in a general hospital centre with trainees. Human factors that may lead to medical error and corresponding to a slice of the cheese involve unskilled operator, a lack of supervision during the procedure, multitasking, exhaustion and heavy workload of the team and absence of caring nurses to help the operator.

Procedural characteristics

The oversight of the guide in the patient means the occurrence of failures during and after the procedure. The operator must have dropped the guide wire during catheterization which is not supposed to happen. Then, he did not notice the absence of the wire, neither did the designed person to dispose of the used equipment notice the missing material.

Localization and material

We have little information about the circumstances of the venous catheter placement described in our case because of the long time interval between the intervention and the discovery of the guide. We know that it was placed in an operating theatre. This localization is usually preferred to the ED or ICU because of the working conditions (available helping team, optimal lighting, anaesthetized patient, single tasking).

The materiel used for CVC placement can be selected to avoid the guide-wire migration inside the patient's body. Indeed, models with a curved end that prevent a total insertion are available.

The availability of an ultrasound and X-ray machine is another important factor of the care quality in central venous access placement.

Performing a plain thoracic radiography is recommended after every central venous catheterization [6]. It is used to confirm the adequate position of the catheter, known as the cavoatrial junction [23], and detect complications such as pneumothorax and haemothorax.

Ultrasound is used to aid insertion of a CVC but is not used in routine practice to check position of the catheter or detect remaining material. However, its use is recommended to decrease complication rate.

Radiological involvement

The post-placement checking radiography is a key moment to detect remaining guide wire. Indeed, the majority of patients remained asymptomatic and many years may pass before a fortuitous detection. Eighty per cent of radiologic errors are perceptual errors; it means that an abnormality is not seen by the radiologist. Pokharel and colleagues showed in their systematic review that 69% of the guide wires went unnoticed by the radiologist after the post-procedure radiography reading [7].

Bad-quality images and views obtained favoured these perceptual errors.

In some studies, the non-detection rates for radiologists working in EDs ranged from 3% to 4.5% [24]. This rate is influenced by the existence of multitasking, high-speed viewing, no previous images availability and heavy workload.

When possible, institutional peer-review programme showed its effectiveness to improve radiological findings [21].

Telling the radiologist about the patient history, the clinical context and the presence of possible superposition is necessary. The radiologist's task can be simplified if radio-opaque superposed materials like monitoring cables are removed or signalled.

These procedures would have avoided the misreading of the post-procedural radiography and a lot of other imageries in our case where the guide wire was characterized as 'superposition material in the paravertebral area'.

All these factors which lead to the final medical error can be summarized in the Ishikawa diagram (Figure 3). It's helpful to individualize each element that can be improved to avoid the error.

Table 2. Summary of the good practice recommendations for central venous catheter placement.

Before the procedure
• Use a institutional procedure known by each member of the team
• Prepare a good working place with optimal lightning and calm
• Ensure the presence of a nursing team to help the operator
• Ensure the presence of a skilled operator or by-side supervisor
• Check the patient's platelet count and INR
• Make an effective hand cleaning
During the procedure
• Be focus on a single task
• Choose the approach according to the patient history and the anatomical specificity
• Use sterile-barrier precautions and antiseptic solutions
• Use ultrasound guidance to perform the catheter placement
• Use a curved end guide-wire model
• Use a single lumen catheter if possible with the appropriate diameter
• Never drop the guide wire during the whole procedure
• Look at the blood colour and pulsatility of the flow to recognize arterial cannulation
• Pronounce aloud "guide out" when inserting the catheter
• Connect the catheter to a pressure transducer to assess for venous waveforms
After the procedure
• Use a postoperative checklist to tidy the used equipment
• Prescribe an X-ray of the chest to look for complication and attest the adequate catheter position. Obtain good quality images and views
• Avoid radiopaque superposed material
• Tell the radiologist about the patient history and clinical context
• Ensure the presence of a skilled radiologist
• Ensure an institutional peer-review programme

INR: International normalized ratio.

From the Ishikawa diagram to good practice recommendations

We discussed the fact that to err is human, which we cannot avoid it. However, the risk can be minimized by implementing structural elements (Table 2).

Central venous catheterization must be carried out by experienced people. If the operator's experience is insufficient, careful supervision must be carried out by an expert. Every health professional involved in the procedure must be focused on this unique task. In addition, team members must be quite numerous and work in good conditions excluding stress and exhaustion. The team should always work in a quiet and well-lit environment. The operator must ensure that he has the correct equipment available (curved end guide wire) as well as an ultrasound and a radiography machine.

Then, during the procedure, the operator must never let go of the guide. When the catheter is inserted, the words 'guide out' must be pronounced aloud. Institutional check list must be written to apply a standardized procedure. After the procedure, the operator and the nursing team must check the presence of guide wire among the used material.

After the procedure, radiography of the chest must be ordered. The clinical context must be indicated to the radiologist. Precautions must be taken to obtain

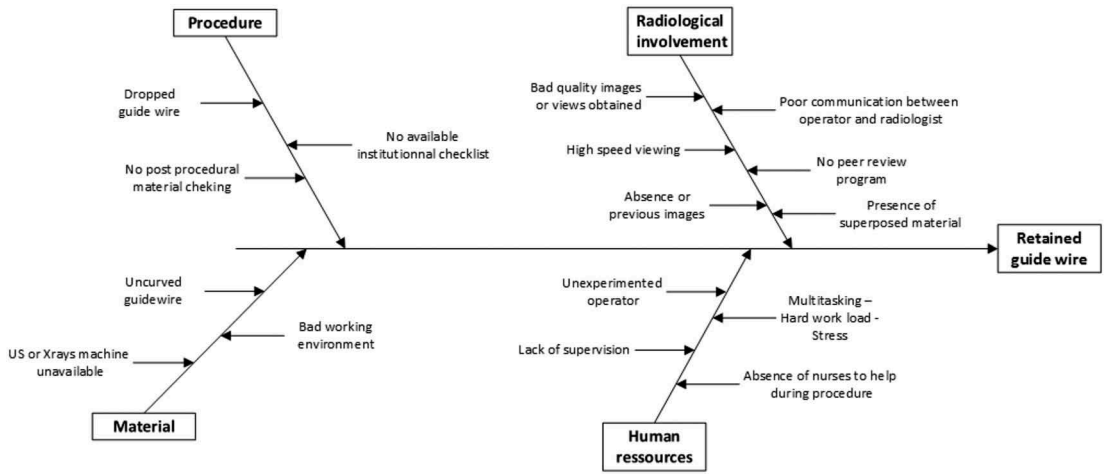

Figure 3. The Ishikawa diagram where all the factors which lead to the final medical error are summarized. It is helpful to individualize each element than can be improved to avoid the error.

good-quality images. The monitoring equipment must be temporarily removed if possible; if not, it has to be clearly noticed. The radiologist should be focused on a single task and spend enough time analysing the image. A peer-review programme is also a good way to reduce image misinterpretation.

Conclusion

Because of human nature, errors will always be possible when taking care of a patient. The Reasons model can be best illustrated by this case report of a long-term overseen guide wire. Indeed, this oversight cannot be attributed to one single responsible person. On the contrary, it can be explained by an accumulation of clumsiness influenced by the context leading to the final problem. From a real-life situation, we identified elements that lead to the final error and classified them to suggest some structural solutions about material and equipment, human resources and procedures.

There is a need to encourage all medical teams around the world to declare undesirable events because discussions about these unfortunate cases are in themselves a way of improving the quality of care. Medicine is made up of mistakes, they show us where we are right now and what we need to do next. They gradually lead to best practice.

In this article, we offer recommendations for good practice to reduce the risk of complications. We invite medical teams to adapt their procedures with these recommendations using the Deming wheel. This quality management method summarized in the acronym PDCA (plan–do–check–act) makes it easy to identify the steps to follow in order to improve the quality of an organization. Finally, the major challenge is to progressively put in place a real culture of spontaneous reporting of adverse effects in hospital teams in order to feed this Deming wheel and make it run faster and faster for the sake of quality and safety of care.

Disclosure statement

No potential conflict of interest was reported by the authors.

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