Guidewire Retention after Central Venous Catheterisation: Prevention and Mitigation using Bow-Tie Analysis

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Abstract. Never events are typically rare but serious incidents in healthcare. They are perceived to be preventable, and include the retention of a surgical instrument in a patient's body. One such instrument is a "guidewire", which is used to help introduce a catheter tube into the venous system of a patient. Following a number of guidewire retentions, these authors investigated contributing factors and examined mechanisms to reduce the risk of further occurrences. This paper presents the results in the form of a bow-tie analysis, which was found to provide an effective way to graphically display and examine the issue.

Keywords. Bow-tie analysis, guidewire, patient safety, retained foreign object.

1. Introduction

In healthcare, 'Never events' are typically rare but serious incidents that are perceived to be wholly preventable, and include the retention of a surgical instrument in a patient's body (NHS England, 2015a). One such instrument is a "guidewire", which is used to help introduce a catheter tube into the venous system of a patient. The catheter can be used for delivering fluids or making measurements.

1.1 Guidewire Insertion Technique

Central venous catheters (CVC) are commonly used for a wide range of procedures under different environments. Regardless of this variation, most anaesthetists and doctors now adopt the 'Seldinger' technique to gain venous access. This technique was proposed as a safer alternative method to threading a catheter through a very large needle directly (Seldinger, 1953). In brief, during this procedure a small needle first enters the target vein. After confirming that the punctured vessel is not arterial, a flexible metal guidewire is inserted through the needle and into the vein, and the needle is removed. With the guidewire in place, a dilator is passed over the wire into the vein and then withdrawn. At this point the catheter is carefully threaded over the guidewire and into the vein until the proximal end (to the anaesthetist) of the guidewire protrudes from the catheter. The guidewire is removed and the catheter sutured to the patient's skin before it is used for the procedure.

Although CVC is widely used with more than 200,000 insertions annually in the UK and 6 million in the USA (Sivasubramaniam and Hiremath, 2008), it is associated with mechanical, infectious and thrombotic complications in more than 15% of patients (McGee and Gould, 2003). A less common and often overlooked potential complication is the inadvertent loss of the guidewire intravascularly. This is in theory a completely preventable never event provided that the operator remembers to grip the wire at all times and removes it after the catheter gains venous entry. Yet has been found to persist at a rate of 1 in more than 3,200 procedures (Vannucci et al., 2013) and the actual unreported incidence may be even higher. Just one case of guidewire retention was notified to NHS England between 1 April 2014 and 31 March 2015 (NHS England, 2015b). The literature data coupled with the high volume of CVCs suggests that a significant number of retentions occur unreported every year in the UK despite attempts to reduce its incidence.

1.2 Bow-ties

Bow-tie analysis is an increasingly popular approach that is used in a variety of high-hazard industries such as mining and aviation (Burgess-Limerick et al, 2014; Pitblado and Weijand, 2014). Over the past few years, bow-ties have also been successfully used in medication safety (e.g., Wierenga et al., 2009) and in intensive care units (Kerckhoffs et al., 2013). Kerckhoffs et al. concluded that the bow-tie model was beneficial to identify both existing and missing barriers for critical events.

Bow-ties combine features of both fault-tree and event-tree analysis to identify initiating events associated with an incident, its contributing factors and consequences, and both preventative and mitigating control measures (Chevreau et al., 2006; De Dianous and Fievez, 2006). At the centre of each bow-tie is an initiating event (or, loss of control of the hazard). In the case of this research, the initiating event was the guidewire (the hazard) being retained inside a patient. The contributing factors and preventative controls are shown to the left of the initiating event, with the mitigating controls and consequences being displayed on the right.

One of the particular strengths of this analysis method is that it provides a quickly understood overview of the risk controls linked to initiating events (Kirsch et al., 2012). Equally, it can show both existing controls and potential/recommended controls for hazards as well as highlighting where gaps in control may exist.

1.3 Aims of research

This paper explores the potential of bow-tie analysis to display and examine the contributing factors, consequences, and preventative and mitigating control measures or barriers associated with guidewire-retention incidents. Hence the question that arises is whether a bow-tie can be viewed as an effective risk communication tool to link together guidewire retention events with their contributing factors, controls and consequences and to show both existing and missing barriers.

2. Methods

2.1 Bow-tie Development Process

As noted earlier, for this research, the initiating event for the bow-tie analysis was defined as a guidewire being retained inside a patient. A list was created of the potential contributing factors to this event, and the potential consequences from it. This was developed through a review of the outputs from the multiple methods used in previous research by the authors (e.g., Ward et al., 2013; Horberry et al., 2014; Teng et al., 2014). Horberry et al., 2014, describe these methods in detail, including interviews with 7 CVC users, observations of catheterisations and two human error assessment methods. For each contributing factor, both the control measures which can reduce the probability of the guidewire being retained (preventive controls), and the measures which can be taken to detect the guidewire after it has been retained (mitigating controls) were identified. Based on previously published findings, three members of the project team (with backgrounds in human factors, safety science and medicine) created a bow-tie. This was reviewed for completeness and accuracy with four staff who were familiar with the CVC process, and further updates were made. The final version is shown in Figure 1.

3. Results

As shown in Figure 1, on the left are contributing factors that underlie this incident and these are linked to the appropriate preventative controls. Once the guidewire becomes lost intravascularly, a range of mitigating controls is available (to the right of "Guidewire retained in patient after CVC") and these can result in either (delayed) detection or a completely undetected incident.

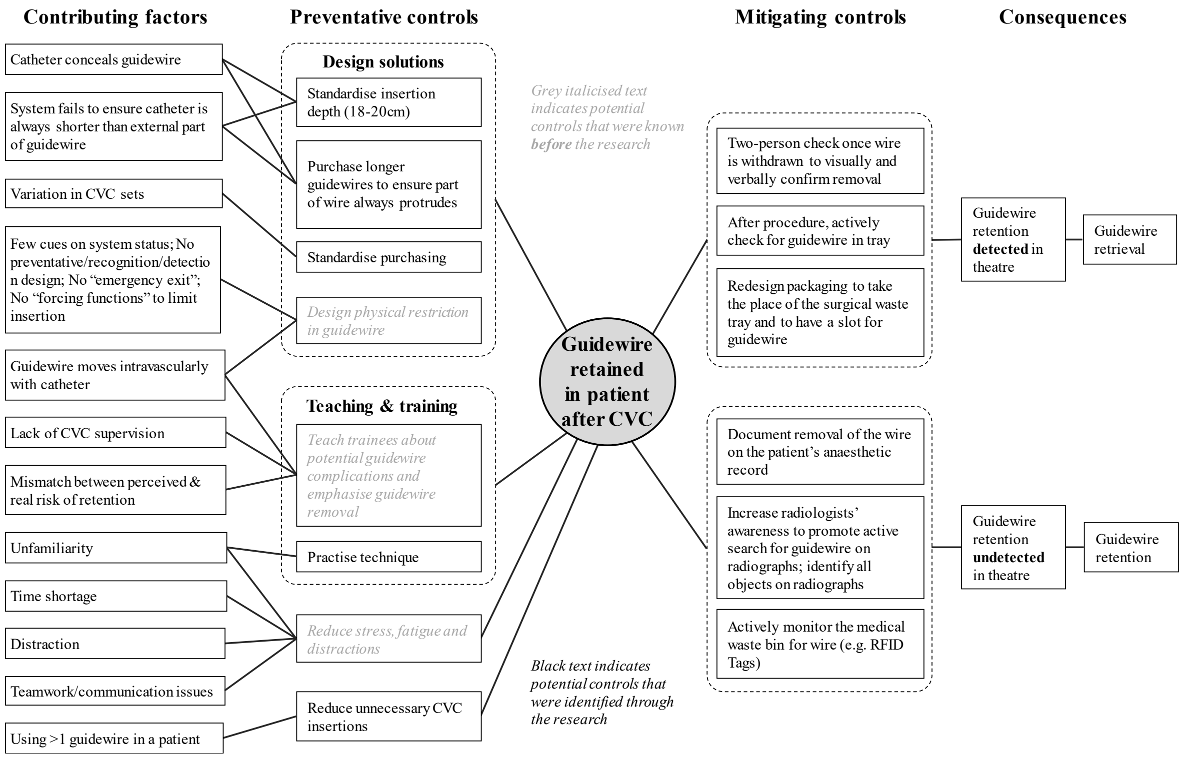

Figure 1 Bow-tie diagram showing contributing factors, controls and consequences behind an event involving a retained guidewire.

The analysis identified 11 contributing factors to guidewire loss. These are linked with 8 potentially implementable barriers, such as standardising the guidewire insertion depth to 18-20cm, and designing physical restrictions to prevent guidewire loss. Highlighted in grey italics are barriers that were known potential measures prior to the research, while those in black are possible measures that emerged through the research.

As opposed to teaching and training the operators to standardise their practice, a number of design solutions were identified in the research. Three (out of 8) preventative and no (out of 6) mitigating measures were known prior to the analysis (see grey text), showing a low number of barriers that were implemented prior to the research. However, after the research further barriers were identified, providing a fairly even spread between prevention and mitigating measures. This can be seen easily from Figure 1.

Overall, the bow-tie visually conveys and compares the current system against the proposed system and recommended changes. Members of the project team, and the four healthcare professionals providing feedback, found it to be easy to see where changes and improvements had already been made, and found the linkages between the different elements in the diagram to be helpful. The staff also found the bow tie to be helpful in identifying where safety could be improved further, such as conducting human factors training to address teamwork and communication issues. Staff liked the visual separation of the preventative controls from the mitigating controls, as this highlighted a current emphasis at the hospital on mitigation rather than prevention, and a potential area of focus for new strategies to reduce the risk of retention further.

4. Discussion and Conclusion

This research work found that a bow-tie analysis provides an effective way of systematically displaying and examining the contributing factors, consequences, and potential preventative and mitigating control measures or barriers associated with a guidewire-retention incident. As such, the main function of a bow-tie can perhaps be viewed as an effective risk communication tool to link together guidewire retention events with their contributing factors, controls and consequences and to highlight both existing and missing barriers.

Conversely, bow-ties can also be used not only to display the results of the analysis, but also to examine broader issues with guidewire use in CVC and to examine where additional gaps exist. As such, it can be a prospective rather than merely reactive medical safety management tool (Kerckhoffs et al., 2013). In the case of guidewires, the prospective nature of bow-ties was revealed in the missing barriers of the left side of the bow-tie diagram illustrated in Figure 1.

Regarding future work, the results being achieved through the bow-tie analysis could be refined further by adopting the System-Theoretic Accident Model and Processes (STAMP) (Leveson 2011). In keeping with the STAMP model, events leading to losses occur only because safety constraints were not successfully implemented. That is, constraints were not imposed on system behaviour to avoid unsafe events or conditions (i.e., hazards). Thus, STAMP is in consonance with prospective analysis and, therefore, changes the emphasis in system safety from preventing failures to implementing behavioural safety constraints (Leveson 2011). Considering bow-ties in conjunction with STAMP, the former can give an overview of what activities keep a control working and who is responsible for that control. In turn, STAMP can reveal the safety constraints that were not enforced by the controller and the appropriate control actions provided but not followed. This effort may comprise a proactive way to help guide the design and development of systems in healthcare.

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