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The Occurrence of Peripheral Intravenous Catheter Complications and an Evaluation of the Methods Utilized to Mitigate Them

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Abstract

Purpose: Despite intravenous (IV) catheters being among the most common invasive clinical devices used in a hospital setting, they are associated with complication rates up to 50% in large medical centers. High patient burden combined with enormous costs to the healthcare system necessitates improvement in IV catheter safety and utilization.

Methods: Total peripheral IV catheter usage rates in the United States were compiled across six reviews. The mean and standard deviation of catheter usage rates were then determined. Peripheral IV catheter failure rates and specific complication rates determined by prospective randomized controlled trials were compiled. Total annual complication rates in the U.S. were then determined using annual catheter usage rates and complication rates.

Results: The surveyed literature reported the use of approximately 225 million peripheral IV catheters per year in U.S. Peripheral IV infiltration was reported as the most common complication (mean incidence of 24%; 54 million cases per year), followed by IV occlusion (mean incidence of 18.8%; 42.3 million cases per year) and IV-associated phlebitis (mean incidence of 15.5%; 35 million cases per year). As total admissions to all U.S. hospitals exceed 36 million annually, a patient will likely receive more than six peripheral IV catheters per hospital admission. With an IV catheter failure rate of 46%, nearly every patient will experience some form of peripheral IV complication.

Conclusions: Other than enforcing better insertion techniques, there does not seem to be a straightforward way to reduce IV complications without the use of an external system. IV and skin monitors have been developed, but these systems incorporate additional monitors and wires into the already crowded intensive care unit (ICU) or emergency room. There exists a need for a simple device that monitors an IV in real time and does not burden the provider or space occupied by the patient.

Keywords: Peripheral IV Catheters; Central IV Catheters; IV Catheter Complications; Complication Rates; IV Monitoring Device

Introduction

Intravenous (IV) catheters, both central and peripheral, are among the most common invasive clinical devices used in a hospital setting, with up to 70% of patients in the United States requiring at least one IV catheter during an episode of care [1]. Because these devices allow intravenous administration of drugs, fluids, and blood products, they are a critical aspect of patient care. In the United States alone, healthcare providers insert between 150 – 300 million peripheral IV catheters and 5 million central IV catheters in hospitalized patients each year [1-3]. Unfortunately, IVs are also associated with high complication rates. Even in large medical centers with dedicated phlebotomy teams, the IV catheter failure rate is between 35% and 50% [4]. These frequent failures are costly to both the

healthcare system and the patient. Types of IV catheter failures and associated complications include phlebitis, infiltration, occlusion, dislodgement, and infection. Current estimates attribute a single case of catheter-associated bloodstream infection (CABSI) to add 7-20 days to the hospital length of stay and cost between $35,000 and $56,000 per episode [2-4]. Combined with such high catheter complication rates, the costs of managing these infections total nearly $2.3 billion annually in U.S. intensive care units alone [4-6].

The most studied IV catheter complication is phlebitis, or inflammation of the vein in which the catheter rests. More severe cases of phlebitis can lead to thrombosis or precede frank infection. Phlebitis can be caused by mechanical, chemical, and infectious mechanisms, or any combination of the three. The most frequent form of IV catheter failure is infiltration, or leakage of fluids into the surrounding tissue due to penetration or erosion of the catheter into the vessel wall. IV infiltration that involves a caustic agent is known as extravasation, which can lead to extensive tissue injury. Occlusion of a catheter represents another common cause of catheter failure. Defined as a loss of the catheter's ability to properly infuse fluid, occlusion can occur due to mechanical obstruction, such as kinking, thrombosis, or catheter migration.

Besides the consequences of IV catheter failure noted above, another very important consequence is the cost to the patient. A catheter failure causes unnecessary discomfort, disruptions in the continuation of care, and can be compounded by the need for a new IV access site. Catheter failure can also lead to potentially life-threatening complications such as sepsis, interruption of critical parenteral therapy, and tissue loss and deformity. The ongoing risk of IV access to the patient combined with the enormous costs to the healthcare system deserves improvement in IV catheter safety and utilization.

Methods

Total peripheral IV catheter usage rates in the United States were reported in six studies. The review conducted by Zingg and Pittet [1] discussed CABSI, which they describe as the most serious yet understudied complication associated with peripheral IV catheter usage. They reviewed important risk factors of CABSI as well as thrombophlebitis, including those related to the catheter itself, the properties of the drug infused, and patient and healthcare associated factors. The cross-sectional study conducted by Alexandrou *et al.* [2] reviewed over forty thousand peripheral IV catheter insertions in 51 countries and found large discrepancies between recommended management guidelines and actual practice, suggesting that the high complication rate may be driven by this difference. The review conducted by Becerra *et al.* [3] included 13 studies evaluating the prevalence, risk factors, and outcomes of idle catheters – peripheral IVs left in situ for a certain period of time without being used. The authors found that idle catheters are associated with higher rates of complications. The randomized trial conducted by Rickard *et al.* [7] concluded that clinically indicated peripheral IV catheter replacement was as safe as a routine replacement, a common recommendation that subjects patients to unnecessary discomfort and increases equipment cost and employee workload. The review conducted by Maki *et al.* [6] analyzed 200 studies to better understand the risk of bloodstream infections associated with peripheral and central IV catheters, arterial catheters, and peripherally inserted central catheters. They concluded that all of these devices posed a risk of CABSI, despite most infection control efforts focusing on the more invasive devices. The study conducted by Alexandrou *et al.* [8] assessed the prevalence of peripheral IV catheters in 14 hospitals in 13 countries and found significant variation in the characteristics, management, and usage rates of these devices from different areas of the world.

The mean and standard deviation of catheter usage rates were calculated based on the results reported by the previously mentioned groups. Peripheral IV catheter failure rates, along with specific complication rates determined by prospective randomized controlled trials, were also compiled [4]. Total annual complication rates in the U.S. were then calculated using annual catheter usage rates and complication rates.

Results

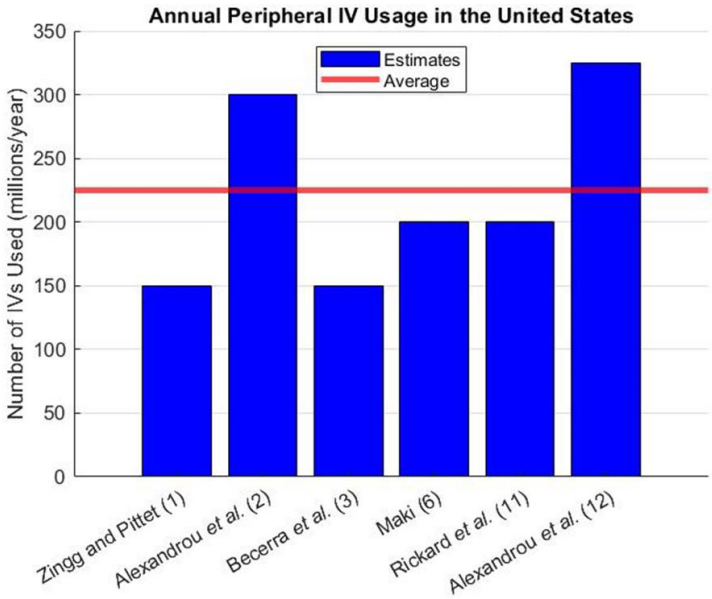

Figure 1: Graph displaying number of peripheral IV uses (million) from six references

Between 150 million and 300 million peripheral IV catheters are used in the U.S. each year (mean = 225 million, SD = 82.2 million). Figure 1 represents estimates of numerous reviews: A) Zingg and Pittet [1], B) Alexandrou *et al.* [2], C) Becerra *et al.* [3], D) Rickard *et al.* [7], E) Maki [6], F) Alexandrou *et al.* [8]. Given that total admissions in all U.S. hospitals exceeds 36 million annually, a patient will receive an average of more than 6 peripheral IV catheters per hospital admission [9].

The previously mentioned literature sources were also evaluated with the intent of identifying the total complication rate for IV catheters. A mean failure rate of 46% was calculated across reports. The individual complication rates for various IV complications were also calculated. Peripheral IV infiltration is the most common complication, with a mean incidence of 24% (SD = 7.2%). The second most common complication is IV occlusion, with a mean rate of 18.8% (SD = 11.8%). IV associated phlebitis has an average incidence of 15.5% (SD = 16.9%). Given this data, total annual peripheral IV complications in the United States for infiltration, occlusion, and phlebitis are 54 million, 42.3 million, and 35 million respectively (Table 1).

Complication Type	Range	Mean
Phlebitis	0.1% - 63%	15.5%
Infiltration	15.7% - 33.8%	24%
Occlusion	2.5% - 32.7%	18.8%

Table 1: Failure modes of IV catheters compared to their associated rate of occurrence

Although no studies directly examine the costs of IV catheter complications, a liability analysis of anesthesiologists by Liau describes monetary compensation for peripheral catheter claims [10]. Table 2 analyzes complication type and cost. Though this only examines the medicolegal aspect of IV complications, it sheds light on the magnitude of the cost incurred by hospitals, physicians, and patients.

Complication Type	Payment Range	Median Payment
Skin slough or necrosis	$1,680 - $123,826	$53,233
Swelling/inflammation/infection	$275 - $35,397	$9,300
Nerve damage	$3,100 - $973,250	$39,725
Air embolism	$20,800 - $3,302,700	$260,000
Total	**$275 - $3,302,700**	**$90,565**

Table 2: Complication type and the associated cost

It should be noted that total admissions to all U.S. hospitals exceed 36 million annually, which means that nearly every patient will experience some sort of peripheral IV complication, whether it be infiltration, phlebitis, or occlusion.

Discussion

Causes of IV Complications

There are a large number of factors that can contribute to IVs failing. Some research has shown that various components of the IV, such as the adhesives/dressings used, size of the catheter, and bend of the catheter, could lead to complications [2,11,12]. Different use parameters of the IV, such as the drug being administered and IV insertion location, have also been shown to increase complication rates [2,11-16]. Some groups have determined that flow characteristics, such as the infusion rate and the venous flow rate, can lead to the onset of IV complications [13,17-19]. Additional research has shown that IVs started in the field and not the emergency department, are more likely to become dislodged [11,20].

Attempts to Mitigate IV Complications

In order to mitigate the occurrence of these events, different groups have attempted various preventative measures. Some groups have attempted to maintain or improve the quality of the IV by routinely flushing it, providing adequate adhesive selection, and enforcing better insertion techniques [14,21-23]. For those measures, reduction in complication rates was only reported by the group that enforced better insertion techniques [14]. The main focus area for IV complication prevention appears to be centered on determining if clinically indicated replacement or routine replacement is more ideal. The CDC recommends routine replacement [24-26], but all studies on the topic have shown that there is no statistical difference in complication reduction between the two [7,14,27-29]. Both Rickard and Abolfotouh recommended replacing the IV as soon as it is clinically indicated [7,14].

Need for IV Function Monitoring Device

Other than enforcing better insertion techniques, there does not seem to be a straightforward way to mitigate the number of IV complications without the use of an external system. One group proposed using an IV drip monitor to monitor the IV for instances when a complication arises [30]. A commercially available option in Europe is the ivWatch, which monitors the patient's skin for signs of infiltration. Both systems incorporate additional monitors and wires into the already wire-plagued and monitor-plagued emergency/ICU room. There exists a need for a simple device that monitors an IV in real time and does not burden the caretaker or space in an emergency room or intensive care unit.

Conclusions

The physical burden imposed on patients as well as the economic burden imposed on the healthcare system caused by peripheral IV catheter-related complications include longer lengths of stay, higher risk of death, and increased equipment and legal costs [31]. Further study is needed to address the risks of peripheral IV catheters specifically, including changes to federal and hospital level policies, insertion techniques, and technologies aimed at minimizing complication rates. Additionally, a nonintrusive device that could reduce the complication rate associated with peripheral IV catheters would benefit hospitals, healthcare workers, and patients alike.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Ethical statement

This article does not contain any studies involving human participants performed by any of the authors, thus approval from the institution's Ethics Committee was not necessary.

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