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Review

Peripherally inserted central catheters in critically ill patients – complications and its prevention: A review

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ABSTRACT

Peripherally inserted central catheter (PICC) is extensively used in critical care settings, because it plays a vital role in providing safe central venous entry. However, PICC is associated with several complications, which should be detected to shorten the duration of patients' improvement, reduce health care cost, and lessen the incidence of various PICC-related complications. Therefore, this study aimed to outline current literature on PICC procedures, potential complications, and measures for prevention. Understanding evidence-based guidelines regarding insertion technique, early detection of complications, and care bundle of PICC is significant in complication prevention. Implementation of education, training, and appropriate multidisciplinary approaches on PICC care among nurses and caregivers is the key to preventing complications. Thus, the strict care of indwelling PICC lines, the targeted and reasonable PICC-associated complication prevention, and nursing care have a major clinical significance in reducing the occurrence of potential PICC complications.

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1. Introduction

Since the 1980s, peripherally inserted central catheters (PICC) have been popularly used to smoothen vascular access since the 1980s. Critically ill patients are at elevated risk of potentially life-threatening complications; therefore, PICCs play a pivotal role in providing care for those patients because they serve as central venous access for antibiotics and chemotherapeutic agents during long-term intravenous drug therapy [1,2]. PICCs are inserted in more than 2.5 million people worldwide annually in acute care facilities and in about 5 million people in the United States [3]. PICC has become a salient tool for critically ill adults and children, because it provides long-term intravenous access due to its different advantages, including ease of insertion, short procedure time, few complications [4,5], reliable form of intravenous (IV) access, and high rate of patient satisfaction [6]. Although PICC has numerous benefits, some literature reported an increased risk of PICC-related complications, including venous thrombosis, catheter-related bloodstream infection (CRBSI), and mechanical failure (PICC

migration, fracture, and obstruction) [7–14]. Some studies reported infection as the most common and severe complication of PICC [6,7]; its incidence rate varies from 16.4% to 28.8% [15]. Similarly, several studies have shown that critically ill patients are at risk of PICC-related thrombosis, thereby making it the second major complication [6,7]. According to one study [16], the prevalence of PICC-associated venous thrombosis in critically ill patients is 13%–91%. Overall, complication rates increase in oncology patients from 35% to 65% [17]. Likewise, PICC-related mechanical complication is reported in a broad range of rates from 0 to 48% [18].

The ongoing occurrence of PICC-related complications is a concern. Several studies were done to prevent such difficulties. The PICC team should adopt interventions for patients to minimize complications, which may differ from patient to patient. Strengthening the practice of sterile technique, strictly disinfecting the puncture site, hand washing before handling the catheter, and reducing manipulations can also prevent catheter line-associated bloodstream infections [17]. Similarly, a retrospective study demonstrated that confirming PICC tip in the distal third of the superior vena cava (SVC) by using either post-procedure chest X-ray or ultrasound (US)-guided PICC placement can effectively alleviate PICC-related deep vein thrombosis in the upper extremity (UEDVT) [19,20], with an incidence rate ranging from 4.8% to 2.9%

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[21]. Thus, reviewing current scientific evidence regarding PICC complications and its preventive measurements is important so that nurses and caregivers dealing with PICC would be aware of the standard practices in minimizing the complication rates. Consequently, patients with PICC may gain satisfaction and quality of life during the course of their treatment. By contrast, scientific evidence on measures to prevent PICC complications in general is limited. Hence, we seek to devise information that can help to implement strategies to improve the patient outcome and reduce health care costs and incidence of PICC-associated complications to fill these knowledge gaps. Our study aims to furnish an overview of the current literature concerning PICC-related complications and prevention strategies.

2. Search methods

A literature search was done through Cumulative Index of Nursing and Allied Health Literature, PubMed, Embase, and Google Scholar for articles, including PICC and its complications. Preventive measures published from 2006 to 2017 were the focus of the search. The following keywords were used: complication, critical care, critically ill, PICC, and prevention. The Boolean phrases used to clarify the search quality results were as follows: "PICC & critical care" "PICC & ICU" "PICC & critically ill" "PICC & complication" and "PICC & prevention". Reference lists of the selected articles were evaluated for additional papers. Articles were considered suitable for the inclusion criteria if they evaluated the preventive measures of PICC-associated complication in critical care settings. We excluded studies that focused on PICC outside the hospital setting, as well as those that are not in English, pre-2006 dated, and unpublished research theses and dissertations.

3. Current PICC application situation

Currently, PICC insertion is carried out via aseptic technique by a dedicated professional team of trained nurses and physicians [7,12,18,22] in a separate sterile ward [22]. Catheter length is measured from insertion point to the middle point of the sternum or up to the xiphoid process according to the indwelling vein. A catheter is inserted through blind cannulation or without US guidance, and a catheter tip position is later on confirmed radiographically [18,20]. On the contrary, routine portable US is carried out to identify a suitable vein for insertion before PICC placement, whereas chest radiography is done to ensure the position of the catheter tip at the distal third of SVC [12,22–24]. The catheter introduction site is fixed with suture free technique, as it has a significant decrease in dislodgement and unplanned removal compared with tape securement [13] and is later dressed with chlorhexidine-impregnated transparent films. Similarly, the catheter is flushed with 10 ml normal saline (NS) immediately after placement, each use, and once a week when not in use [7,13,20,21]. However, the concept of using NS for flushing and locking is not easily accepted by Chinese PICC nurses, as they prefer regular heparin saline (HS) for flushing and locking of a catheter in everyday nursing practice until now [25]. The PICC size used is 4F or 5F according to the vein diameter, and 5F PICC is only considered for a patient who requires TPN [12]. Dressing for the hospitalized patient must be changed every 7 days or as needed (if drainage, bleeding, or moisture is present) [18]. Relatively, polyurethane PICCs are increasingly favored by manufacturers because of their high flexibility and great wall strength, which allow the production of small-sized and high-flow catheters with great inner lumina [7,13,26] and the significant tolerance to high flow rates with low risk of rupture [27]. Recently, the trend of using polyurethane PICC lines dominated the market, with 70% of all PICC lines

manufactured from polyurethane material seen in the United States. This rate may rise to 95% by 2017, thereby limiting silicon catheters nearly out of market [27].

4. PICC procedure pathway

Standards for PICC insertion are needed to support and intensify best nursing practice to promote patient safety and welfare. The following steps serve as basis for specific nursing protocols, policies, and procedures developed accordingly.

- The purpose of procedure must be explained to the patient and family members prior to starting any procedure.
- The arrangement of required equipment and the procedure must be carried out by various trained personnel, including a specialized trained nurse, anesthesiologist, and interventional radiologist, either in bedside or operating room or specialized sterile area [7,12,13,18,22], according to hospital policy.
- The skin must be prepared by applying chlorhexidine solution before catheter insertion [13,20,28,29], and the surrounding area must be covered with sterile drapes to limit infection. Hand hygiene, gloving, masking, and gowning are essential for care providers [15,20].
- The tourniquet must be placed just below the shoulder, a sterile gel must be applied at the expected site of cannulation, and the suitable vein for venipuncture must be determined through US guidance to improve the successful access [12,13,20,22–24,30].
- Lidocaine 1% is injected intradermally under sterile conditions. A thin needle must be inserted systematically into the vein under US guidance, and the needle insertion site must be enlarged by using a scalpel blade to introduce the guide-wire through the needle. The tourniquet must be loosened once blood return is observed. Then, the needle must be removed, and the PICC line must be inserted through the vein over the guide-wire to the SVC [7,30,31].
- The indwelling guide-wire must be pulled out, and the injection cap must be attached to the catheter hub.
- The catheter should be measured again for blood return and flushed with NS; the catheter tip position at the distal third of SVC must be verified via chest radiography [7,13,20,21,30,31].
- Last, the catheter insertion site must be fixed with the suture-free technique and dressed with chlorhexidine-impregnated transparent films [13,32].
- Post-operative management is significant for maintaining PICC patency and preventing complications. Proper hand hygiene and aseptic technique should be practiced during handling, changing the dressing, administration of intravenous infusions and medications, and replacement of soiled dressing at regular time intervals [15,17,22,24,31,33].
- Recording and reporting are done to monitor a patient's conditions and progress and to communicate with other caregivers, which help maintain effective care and prevent potential PICC-associated complications.

5. Complications

5.1. Factors associated with complications

5.1.1. Patient status

Critically bedridden ill patients for >72 h are likely to have elevated D-dimer and comorbidities, which are the leading causes of PICC-related venous thrombosis [16]. Studies show that patients whose PICC tips are positioned in regions other than the SVC have felt higher venous thrombosis [8,19,20,34]. Also, a patient

receiving erythropoietin-stimulating agents and specific chemotherapeutic agent (e.g., fluorouracil and capecitabine) infusion may be at increased risk of PICC-DVT (Deep vein thrombosis) [12,19,22,35]. Furthermore, immunosuppressed patients are likely to develop catheter-related infections [1,34,36]. After a successful placement, patients' abnormal movements and high intracranial pressure with severe nausea, vomiting, hiccups, and constipation may lead to mal-positioning of the catheter tip [35,37,38]. Barrier et al. [10] found that patients with <14 days PICC who received more than four doses of antimicrobials daily also experienced high complication rates.

5.1.2. Vein selection

Comparatively, a catheter inserted into small veins within the upper extremity causes decreased blood flow than that inserted into the central veins, which is a plausible etiology of increased PICC-related thrombosis [19,22,39]. As reported, placement of the catheter into an azygous vein is rare. However, azygous catheter tip placement can be used as an alternative in a patient with comorbidities, such as severe venous occlusion; this vein is highly responsive to complications [9]. Also, placement in the small vessel (6–8 mm) results in an increased chance of thrombus development, vessel aperture, stenosis, and extravasation, [19,22,40]. Hence, the insertion of the PICC line other than in veins of the arm (e.g., chest, groin, and neck) is associated with the risk of infection; only few organisms may be found on the arm because of its distance from the mouth and the nose [7,14].

5.1.3. Catheter choice

PICC materials are correlated with a variable incidence of infection. For instance, silicone catheter is associated with a prominent infection risk and microorganism colonization compared with polyurethane catheter [7,13,27]. The absolute catheter resembles a single lumen polyurethane catheter with a small diameter and high volume. A large PICC may increase venous thrombosis and occlusion incidence [13], although this assumption has not been proven in a randomized study. The use of PICCs $\geq 5F$ diameter increased UEDVT ratios [6,12]. Also, double lumen PICCs are associated with higher complication rates (30.8/1000) compared with single lumen PICCs (17.2/1000) with a smaller gauge [10]. Liem et al. [6] described the close relationship between PICC diameter and thrombosis, with thrombosis rate of 1% with 4F, 6.6% with 5F, and 9.8% with 6F; thrombosis was not associated with 3F PICCs. Similarly, the use of large PICCs may increase the likelihood of thrombosis [13], whereas a small catheter can cause mechanical problems [13,37,39]. However, this assumption has not been endorsed in randomized studies. Lack of timely flushing of the catheter may also cause catheter blockage, because the blood attached to the wall of a tube may pile up. Small lumen diameter leads to high chance of blockage occurrence [37]. Also, to allow blood to pass through the heart carrying the catheter towards the vena cava, it is imperative to consider slow insertion of the. Accelerated threading the catheter may enhance the risk of catheter malposition [22,35].

5.2. Caregiver factor

Several studies found that inadequate knowledge and practice of healthcare personnel regarding PICC insertion and caring technique may lead to various complications. Failure to follow aseptic techniques during catheter insertion and routine care maintenance, lack of education and skill to assess the sign of infection, and poor hand hygiene, while caring for the patient [7,13,18,21,29,41], are the primary causative factors of catheter-related infection.

5.3. Major complications

Major complications can be defined as severe PICC complications that often result from the early removal of the peripherally inserted central catheter line. Infections/sepsis, thrombosis, and mechanical failure are the three major types of complications [1,7,10,42].

5.3.1. Infective complication

A retrospective evaluation [43] was conducted to appraise the complication rate of bedside PICC insertion in the ICU during 1 year, and central line-associated bloodstream infection rate is 2.92%, whereas the prospective study by Bertoglio et al. [12] reported 2.1% catheter-related infective complication (0.95%) per 1000 catheter days; similarly, Yap et al. [42] reported 5.7% or 0.73% complication per 1000 catheter days. Furthermore, Fairhall [7] reported a PICC-associated infective complication rate of 4.3% at a rate of 0.49 per 1000 catheter days compared with another study, where infection rate occurred with a higher rate of 25.3% at a rate of 11.1 per 1000 catheter days [44]. Likewise, Levy et al. analyzed 279 peripherally inserted central catheters placed in a tertiary care pediatric hospital and reported a total infection rate of 4.4/1000 catheter days [13]. As discussed, various factors contribute to PICC-associated complications, which must be addressed and minimized accordingly.

5.3.2. Thrombosis formation

Several studies have reported that critically ill patients have a high chance of having PICC-related venous thrombosis [41,45–47], which is supported by the retrospective cohort study of Nolan et al. in the medical intensive care unit at Mayo Rochester between 2012 and 2013. They estimated the incidence rate of catheter-related deep vein thrombosis to be 4% and 1% (4.6 and 3.1 per 1000 catheter days). Likewise, a meta-analysis by Chopra found that the incidence of PICC-associated venous thrombosis in a critically ill patient was 13%–91% [16]. A prospective study by Walshe et al. reported a complication rate of 32.8% and 10.9/1000 PICC days among 351 cancer patients [44].

A prospective study by Bertoglio et al. [12] reported 11.7% catheter-related venous thrombosis complication (0.30%) per 1000 catheter days. Yap et al. [42] reported a catheter-related thrombosis rate of 4.5% or 0.58% complication per 1000 catheter days. Furthermore, Fairhall [7] reported a PICC-associated thrombosis complication rate of 2.4% at a rate of 0.28 per 1000 catheter days compared with another study, in which deep vein thrombosis rate occurred at a lower rate of 0.7% (0.30 per 1000 catheter days) [44]. The smallest PICC that likely meets the patient's need should be inserted, and a post-insertion X-ray should be conducted to assure that the catheter tip resides in the lower third of the SVC to minimize the chance of thrombus formation [7].

5.3.3. Mechanical failure

Mechanical catheter complications are rarely life threatening, but they may also result in the obstruction of treatment and require the replacement or removal of PICC. Inner lumen occlusions are common with rates of up to 10.6/1000 PICC days [13]. A prospective study by Bertoglio et al. [12] reported 4% catheter-related occlusion complications (0.41%) per 1000 catheter days, and Yap et al. [42] reported 3.4% catheter-related obstruction rate. Furthermore, Fairhall [7] reported a PICC migration rate of 4.2% at a rate of 1.69 per 1000 catheter days compared with another study, which reported a catheter damage rate of 32.8% (14.4 per 1000 catheter days) [44]. Catheter malposition also causes thrombosis. Nurses must be alert to mechanical complications, because coughing and vomiting are very common symptoms in critically ill patients. Malposition leads to serious complications, and must thus be confirmed via a chest x-

ray to ascertain the distal tip position. For instance, the PICC tip positioning proximal to the superior vena cava (SVC) leads to thrombosis formation and phlebitis; if the peripherally inserted central catheter tip is misplaced into the distal right atrium or right ventricle, cardiac arrhythmias may occur [6,7,16,48]. Therefore, ensuring the catheter tip position is important in preventing catheter migration or dislodgement. The incidence of catheter migration or dislodgement, including catheter slide or extrusion and catheter drift is 5%–31% [6].

Overall, different types of complication rates in critically ill patients were reported in literature. This study featured infection, deep vein thrombosis, and mechanical failure as the most common complications. Comparison of the complication rates in four studies shows that an infection is the most frequently occurring complication, which is followed by thrombosis in the study of Bertoglio [12] and Yap et al. [42], and by mechanical failure in Fairhall [7], Bertoglio [12], Haider [44], and Yap et al. [42]. One of the objectives of the current study was to position the finding on PICC complication rate in critically ill patients. This purpose has proven to be challenging, as this study also aims to focus on prevention strategies according to the findings. The findings and possibilities of the study indicate why PICC must be discussed. Table 1 outlines the comparison of different PICC complication rates in critically ill patients.

5.4. Minor complications

Minor complications are those that can be corrected with secondary treatment and do not require PICC removal. Some of these complications are phlebitis of a catheterized vein, pain or bruising at the site, skin reactions to the dressing covering the insertion site, sluggish blood withdrawal, or resistance when flushing the PICC [7,13,49]. Such problems do not need hospitalization >24 h and re-hospitalization except for clinical evaluation [50]. Skin reactions to the dressing are common but usually respond well to minor treatment. As soon as the dressing is changed, the skin reaction typically remains after a few days. Inflammation of the intima of a vein is characterized by pain, redness, and swelling at the site is phlebitis. It can occur within the first 24 h and commonly responds well to hot compress. Flushing or sluggish blood withdrawal resistance may be due to fibrin sheath formation around the catheter or a fibrin tail at the distal end of the catheter. This resistance can usually be corrected by instillation of urokinase [7,25,29,30]. Therefore, minor PICC line complications can often be corrected with conservative management or minor treatments, and do not require early PICC line removal.

6. Preventive measures of complications

6.1. Infection prevention

Infection is the most severe common complication of PICC and also life threatening if not corrected in time. The PICC team should extend the concept of strict sterile technique and disinfection

puncture site. The more frequently the dressing is disturbed; the more likely does the Central Venous Access Device (CVAD) insertion site interferes with higher potential for infection [8,15,29,33,49,51]. Transparent dressing should be preferred because it can be left in position for seven days, which provide its integrity without compromise. Also, using transparent dressing helps to easily observe cases of damage, wet foil, foreign bacteria, and the presence of blood oozing from the insertion site, thereby contributing to the detection of infection on time [20,32,37,52–55]. A study suggested that the incidence of colonization infections and CRBSIs could efficiently be reduced following the Central Line Bundle (CLB) guideline; catheter-related infections (CRIs) decreased from 10.0 per 1000 catheter days to 2.2 per 1000 catheter days before and after the intervention, respectively, and colonization infections decreased from 6.9 per 1000 catheter days to 2.2 per 1000 catheter days [15]. CBL guidelines have the following conditions: hand hygiene, dressing management, filling and sealing the catheter tube, and daily assessments by duty nurses. Hand hygiene can be maintained by disinfecting the hands, strict hand washing with the seven-step hand washing method, and maximal barrier precaution (masking, gloving, gowning, and using sterile drapes) before inserting the PICC and touching the catheter or dressing [1–3,15,56,57]. Likewise, a dressing has to be done the day after catheter insertion and changed every week afterward. There is a need to assess catheter and dressing daily by responsible duty nurses for redness, swelling, and inflammation; nurses should also present an evaluation for the need to remove the catheter according to clinical indications [15,56–58]. Infection preventive strategies also include education and training of healthcare personnel [7,13–15,21,28,29,41,43] who take part in catheter insertion and maintenance by using maximum sterile barrier precaution during catheter insertion and 2% chlorhexidine for skin antisepsis [28,29,33,51,58,59]. A study showed that 2% chlorhexidine-based alcohol solution is more efficient for decontamination than povidone-iodine, which can be used as decontaminant for cleaning injection hubs or connectors [29]. Similarly, a randomized controlled trial was conducted to evaluate the efficacy of three antiseptic solutions for skin antisepsis at catheter site insertion, including 10% povidone-iodine, 70% alcohol, and 2% chlorhexidine gluconate. Chlorhexidine treatment (2%) is associated with the lowest rate (2.3 per 100 catheter days) of catheter-related infection, 7.1% for povidone-iodine, and 9.3% for alcohol. This result suggests that 2% chlorhexidine gluconate solution markedly decreased catheter-related infection [7]. Simply, the skin is a good barrier to microorganisms. Once PICC insertion begins, this cutaneous barrier is broken and provides an easy access to microorganisms. Thus, a significant infection prevention strategy is to disinfect the skin before PICC insertion and to care for it thereafter. Comparatively, NS has several advantages over heparin solution. It prevents the manual preparation of HS by nurses, which is a risk of transmitting contamination that results in BSI. Thus, NS is considered essential in preventing and controlling infusion-related infection [13,20,25,30,60] (Table 2).

Table 1
Comparisons of PICC complication rate in critical care setting.

Study	Number of patient	Number of PICCs	Complication rate [% (per 1000 catheter days)]			Removal due to complication [% (per 1000 catheter days)]
			Infection	Deep vein thrombosis	Mechanical failure	
Fairhall [7] (2008)	156	164	4.3 (0.49)	2.4 (0.28)	4.2 (1.69)	9.75 (1.2)
Bertoglio et al. [12] (2016)	267	291	2.1 (0.95)	11.7 (0.30)	4 (0.41)	10 (1.33)
Haider [42](2009)	146	146	25.3 (11.1)	0.7 (0.3)	4.1 (1.8)	32.8 (14.4)
Yap et al. [44] (2006)	73	88	5.7 (0.73)	4.5 (0.58)	3.4	15.9 (2.0)

Table 2

Summarization of prevention strategies of PICC associated complications as reported in the literature.

Prevention strategies of PICC associated complications
<p>During Insertion</p> <ul style="list-style-type: none"> • Aseptic technique • Hand washing before insertion and manipulation of a catheter • Maximal barrier precaution (mask, gown, glove, sterile drapes etc.) • Appropriate vein selection • Use of polyurethane catheter • Determine catheter type and size according to need • US guidance catheter insertion • Cutaneous antiseptics; chlorhexidine solution • Using SecurAcath device <p>Maintenance</p> <ul style="list-style-type: none"> • Confirm catheter tip position (post insertion chest x-ray) • Remove PICC catheter when no longer essential • Monitor insertion site frequently • Replace dressing the day after insertion, then once a week when not in use or whenever required • Systemic anti-coagulation with a low dose of HS • Flush catheter with NS before administering any medication using >10 ml syringe <p>Technology</p> <ul style="list-style-type: none"> • Urokinase instillation to prevent blood reflux • Push-pause technique while flushing • In-service education and training to nurses and caregivers • Develop specific PICC guidelines and prevention strategies in every PICC unit in the hospital

Note: HS = heparin saline; NS = normal saline.

6.2. Prevention of venous thrombosis

PICC-associated DVT can be reduced with increased staff education and training on insertion, monitoring, and reporting, and accurate selection of smaller diameter PICC [39,61], which should be based on cost-effectiveness, safety, resistance to increasing fluid volumes, durability, and low complication rates [61]. However, lack of timely flushing of the tube causes the accumulation of blood attached to the wall of a conduit, thereby resulting in catheter blockage. The smaller the lumen diameter, the higher the blocking rate. Thus, PICC nurses should understand how to conduct the gentle flush with push pause technique using different types and specifications of catheters [25,37,62,63]. A retrospective study found that the incidence of symptomatic catheter-related DVTs was 1% with 4F catheters, which climbed to 9.8% when the 6F catheter was set [41]. Therefore, 4F catheter use alleviates the rate of catheter-related DVTs [39,41]. Similarly, a retrospective study demonstrated that confirming the PICC tip in the distal third of superior vena cava using either post-procedure chest X-ray or US guidance PICC placement is effective in alleviating PICC-related UEDVT [8,17–19,23,24] incidence from 4.8% to 2.9% [21]. US-guided PICCs have a low rate of thrombosis [20,64] compared with the previous practice of using anatomical landmarks and palpation for insertion. The thrombosis rate declined from 9.8% to 1.9% with the use of US guidance [23]. Likewise, low-dose heparin is commonly administered as a prophylaxis [19,25,62,65] to flush and lock peripheral venous catheter, thereby maintaining its potency and preventing venous thrombosis [25]. However, some studies reported that warfarin at a low dose did not reduce symptomatic or asymptomatic DVT (RR 0.6, 95% CI 0.3–1.3) [66] and authenticated that flushing HS and NS have similar rates of lumen occlusion [49]. Thus, the use of pharmacologic prophylaxis in preventing catheter thrombosis is not suggested in existing guidelines [67]. Hence, further specific studies regarding flushing solutions and PICC-DVT seem necessary.

6.3. Prevention of mechanical failure

PICC migration, catheter occlusion by mechanical obstruction, catheter damage, ruptures, and breakages are types of mechanical

failure. Catheter migration leads to unfavorable outcomes both in terms of financial aspects and clinical management. Thus, Michael Rosenberg, an interventional radiologist in clinical practice in the United States, invented SecurAcath device to minimize the incidence of catheter migration. This device is a subcutaneous securement system that is placed beside the indwelling catheter to prevent its migration [7,20,35,38,63]. Applying SecurAcath device in practice to prevent catheter migration is convenient. US-guidance PICC insertion not only enhances the success rate of placement with PICC tip location in the distal third of SVC but also lowers the incidence of mechanical phlebitis and thrombosis, reducing trauma caused by failed attempts [7,20,23,64]. Furthermore, silicon (Groshong™) catheters allows blood to reflux inward, which results in clot formation and the occurrence of snapping or fracturing compared with polyurethane (Arrow™) catheters. Hence, silicon catheter may cause more occlusion than polyurethane, which is flushed daily when not in use [7]. We can then assume that mechanical failure, such as occlusion, breakage, and rupture can be prevented if polyurethane PICC catheter is used. Polyurethane PICCs have great flexibility and wall strength and is capable of tolerating high flow rate significantly with a low risk of rupture [7,27,49]. Another cause of catheter rupture is the accidental application of excessive pressure during flushing because of using syringes smaller than 10 cc, which cause extreme intraluminal pressure to PICC and may result in catheter rupture. Thus, using 10 cc needles or larger is recommended, because they prevent possible catheter rupture and PICC damage [7,35,39,49,61,65].

6.4. Prevention of minor complication

Minor complications, such as phlebitis of a catheterized vein, pain or bruising at the site, skin reactions to the dressing covering the insertion site, sluggish blood withdrawal, or resistance when flushing the PICC do not need hospitalization for >24h and re-hospitalization, except for clinical evaluation; such complications are common but are usually alleviated by minor treatment [7,29,35,38,50]. Pain at the introduction site is usually associated with phlebitis and difficulty in insertion. Heat application over the cannulated vein improves blood flow, and moving the vein wall off the catheter and inserting the smallest PICC possible to meet the

patient's treatment need helps reduce the incidence of mechanical phlebitis [7,50]. A well-hydrated patient has less chance of having insertion trauma and phlebitis. Thus, critically ill patients need to be given 500–1000 ml of IV fluids before insertion [7]. Using polyurethane PICCs is less likely to impede and installation of urokinase, thereby preventing blood reflux into the catheter tubing and sluggish blood withdrawal [35,39,61,65]. Likewise, well-trained nurses must redress the patients and dry the insertion site to minimize bruising and skin reaction around it.

The role of PICC nurses has changed and has become complex because of the high demand for education, skills, and new technology regarding PICC care and its management [45,46,68]. This factor is the reason for the various challenges that nurses and caregivers are facing in caring for patients with PICCs. Increased staff and patient education, trained PICC nurses, and improved insertion techniques can also reduce the rate of PICC complications [7,13,14,18,21,29,44,49], which save cost by diminishing PICC reinsertion and decreasing thrombolytic agent use [7,14]. Russell E et al. monitored various suboptimal results among nurses and reported incidences, such as incorrect documentation, lacking flushing orders, catheter site infection, and improper dressing practice among nurses caring for patients with PICC [69]. Lack of continuous education and training on PICC caregivers was determined as a challenge for PICC insertion and facilitated the integration of care among the care providers [70–72]. In-service education and training for all the working health personnel in a hospital setting in day-to-day patient care are recommended to upgrade their knowledge and skills for improved patient prognosis. We can assume that trainees will have good knowledge, improved performance, and more confidence in their skills. This assumption is supported by a study that evaluated a combined theoretical and practical training course for staff to perform PICC placement. The result showed a significant improvement between pre-training and post-training assessment [70]. Hence, providing training, awareness program, and enhancing nursing capabilities are the key factors in providing PICC-associated risk prevention.

7. Future directions

Although each nurse plays a fundamental role in the management of intravenous devices, PICC should be conducted by trained nurses, physicians, and interventional radiologist because a high level of education, qualification, and appraisal of knowledge of institutional guidelines or protocols help in the identification of the adverse effects of PICC, thereby precluding its potential complications. A growing number of evidence supports the complications addressed above, which must be dealt with. The insertion and maintenance of PICC must be ensured to be within the scope of clinical practice of all nurses and caregivers involved, which can be determined by their education, skills, credentials, training, and maintenance of performance as the desired level of patient's safety. For the best outcome, improvement in the quality of nursing care and management that may allow continuity of record, future studies, and nursing practice enhancement in relation to the insertion and maintenance of PICC must be emphasized. Development of specific prevention strategies and protocols in every PICC unit is significant. Also, much of the future scientific work will depend on the improvement of knowledge of the best PICC practice to decrease patient morbidity, decrease healthcare cost, and to eradicate PICC-associated complications. Well-trained staff and application of theoretical knowledge into practice are the most promising modalities for the future.

Our study involved an ample number of current research concerning PICC in critically ill patients as a whole, and our results may help health care professionals determine the appropriate PICC

device, procedure, and possible complication and its prevention with the purpose of mitigating the potential hazards of PICC in critically ill patients. We included critically ill patients despite our systematic approach, but a well-distinguished age group was not considered.

PICCs may serve as safe and valuable options for intermediate to long-term central venous access in critically ill patients. Under-standing evidence-based guidelines regarding insertion technique, early detection of complications, and care bundle on PICC is significant in preventing complications. Implementation of education, training, and appropriate multidisciplinary approaches on PICC care among nurses and caregivers is key to preventing complications. However, available data that take all of these factors into account in the context of critical care settings are inadequate. Well prospective trials assessing complication and prevention strategies comparing clinical outcomes of PICC in critically ill population are highly needed.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijnss.2018.12.007>.

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