REVIEW ARTICLE

Review on Dislodgement & Securement Risk of Peripheral Intravenous Catheter/Cannula and The Needs of PIVC Securement Device

Zubair Faramir Zainul Fadziruddin, Adi Azriff Basri, Ernnie Illyani Basri

Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

ABSTRACT

Intravenous (IV) infusion of medical fluid is a very common procedure used as part of medical procedure treatment. It is also the best alternative medical administration route when medical administration through orally is impossible. The most common use of VAD is the short Peripheral IV Catheter (PIVC) or recognized as IV Cannula. In spite of that, even with experience used of PIVC in medical practice nowadays the rate of IV access failure is very high which is up to 69%. Intensive research studies shows the dislodgement case is one of the major contributions of PIVC failure. For some reason only a fewer cases are reported to the administration. This article seeks the awareness and risk factor regarding to the prevailing IV access failure using the PIVC. This manuscript reviewed the statistical data of PIVC dislodgement, significant of dislodgement, dislodgment cases among pediatric, medical staff factor related to PIVC dislodgement and alternative of securement device. This manuscript also discussed the needs of new securement device in order to reduce the percentage of PIVC dislodgement from occurs.

Keywords: Intravenous, Catheter, Cannula, IV Securement, IV Dislodgement

Corresponding Author:
Adi Azriff Bin Basri, PhD
Email: adiazriff@upm.edu.my
Tel: + 603-9769 4392

INTRODUCTION

In medical, the term "Venous" is commonly used to indicate or relate to the vein of a human being. While "Intravenous" or shorten as IV literally means "within or inside the vein" where the term is usually used as indicator for a medical fluid administrated into patient's vein through vascular access device (VAD).

Typically, a VAD have a sharp needle catheter as the main component to perform puncturing onto the patient's skin in order to gain access into the vascular line for medical purposes. This type of VAD is generally known as a catheter device. Another essential component of a catheter device is the small flexible hollow plastic tube that channelled medical fluid into the vein. Two type of vascular line to be chosen are the peripheral IV line or central IV line depending of the usage, purpose and medical condition of the patient. Peripheral IV line consist of peripheral vein at the human limb such as arm, hand or feet. Central IV line is referring to large central vein such as superior vena cava (Line at the heart).

The type of catheter used for Central IV line is known as Central Venous Catheter (CVC). The most common VAD for Peripheral IV line is the Peripheral IV Catheter (PIVC) or sometime recognized as IV Cannula. The PIVC is a of short, hollow small plastic cannula into the vein for transferring medicines administration or nutritional fluid through patient's arm or hand (1–4). In some Paediatric cases, the insertion of intravenous access can be at the patient's feet due some several reasons such as failure at first insertion attempt of cannula onto the hand or unclear visibility for venipuncture site because of small vein size.

Although IV catheter is a common used medical device, both PIVC and CVC also related to various compilation including thrombosis, haematoma, sepsis, phlebitis, infiltration, infection, and as well as dislodgement by accidental or non-accidental, where most failure related to PIVC (1,5–20). The current PIVC placement procedure can be clarified as suboptimal (40). Available data record related to first attempt success rage average only between 44% and 46% in paediatric patients and 40% in adult patients (41,43-45). However, the overall complication rate due to the issue of infiltration, phlebitis, occlusion and dislodgement is stated to be 47% in average duration of 44 hours (46,47).

In details, PIVC dislodgement out of vein, partial or complete occurs due to the poor securement of catheter to skin or interference between patient of medical

practitioner (55,56). Occlusion is defined as inability to infuse or inject medications fluids through the lumen (57). Occlusion can be categorized as mechanical (e.g kinking), medication or thrombotic related in origin where it also occur from irritation to the cannulated vein wall which release of thromboplastic substances and platelets (58). Infiltration happened due to the leakage of non-vesicant solution into surrounding tissue (59,60). Meanwhile, phelibitis is defined as inflammation or irritation of vein which can occur through the chemical, bacteria origin or mechanical reaction with PIVC (61,62). Hence, phelibitis complication rates is reported widely between 2% to 80% (63-65).

Among all type of complication, dislodgement is notable as the one of the highest or common issue raised related to PIVC (6,13,22,23). It is reported that the dislodgement or accidental removal is stated to between 6%-20% of catheter failures (56-70). PIVC failure due to dislodgement is recorded more half of IV access insertion and for some reason the dislodgement case is usually unreported (13). Dislodgement also caused other problems concurrently such loss cost of PIVC and lower productivity of medical staff. The patient also getting delay medical treatment that can increase stresses and anxiety. Importantly, it is approximate about 50% of PIVC lines needs to be replaced before the therapy complete which leads to high patient dissatisfaction due to the process of medication delays (41,42,48). Shockingly, there is also case where the PIVC fractured during removal process (21) and need to be removed in a small surgery process. Moreover, these complications from vascular access device failure and infusion also leads to the negative financial implication (49).

Richard (2018) indicated the lowest PIVC dislodgment case due the research is under controlled securement technique variables. Even the dislodgement is the third ranked for type of IV failure, the overall IV failure is almost half (41%) and illustrated occlusion and phlebitis is the main contribution of IV failure. The research also reconfirmed that securement dressing or device does not necessarily lower the PIVC failure rate, as in studies done by Mourea (2018), Marsh (2015), Rickard (2015) and Ad (2011) (13,23,28,32). Also, it is found that IV failure can also cause potential life threatening that caused by infection known as sepsis. For the time being no literature studies being done on potential of sepsis on PIVC. Jumani (2013) and Mourea (2018) showed the dislodgement of PIVC as the highest IV failure distribution. Even dislodgement is not the highest rank of IV failure, the dislodgement case is generally rank the second highest type of IV failure. Except for Rickard (2018) research showed dislodgement rank as the third place even the study is under controlled securement technique. Although Richard's research in 2015 did not mentioned specific rank of IV failure, the research showed 71% of PIVC is not properly installed, as suggested by Mourea (2018) that poor IV securement is rated at 65%. Helm (2015) does not provide specific overall number of sample but it is the only data that compromise most type of IV failure which showed dislodgement have the highest range. The data is also comparable to all other PIVC researches. It seems like Wallis (2014) have the highest number of sample study and showing occlusion is the highest distribution of IV failure with a margin of 52.6% compare to dislodgement. Mourea (2018) is the only literature that is in a form of comprehensive study of IV device dislodgement by using survey analysis. Averagely, the CVC show the lowest tendency for dislodgement compare to PIVC. The lowest IV failure rate for CVC is 20.8% while for PIVC is 36% and it is confirmed that dislodgement is one of the main complications related to IV failure. Hence, this manuscript provide a brief review of PIVC background, the usage of PIVC in medical treatment, statistical data of PIVC dislodgement, significant of dislodgement, dislodgment cases among pediatric, medical staff factor related to PIVC dislodgement and alternative of securement device. Moreover, authors also discussed the needs of new securement device, improvement of current securement device, design criteria of new securement device and also the recommendation in order to reduce the percentage of PIVC dislodgement from occurs in the medical field.

BACKGROUND OF IV ROUTE MEDICAL TREATMENT

The earliest history of IV infusion can be traced back to 1492. In Rome, a doctor resulted death of Pope Innocent VIII after trying to treat his unwell patient by direct blood infusion without any device. Around that time, several other IV infusion are attempted also contributed into poor result that the procedure is slowly abandoned. In 1658, the IV infusion method is revisited when Christopher Wren became the first man tried to experiment a working IV infusion device by using animal organ with pig and quill's bladder (24). Approximately 200 years later a cholera pandemic attacked Scotland in 1832 after the disease travelled from India to Europe. A study is carried out on the patient condition and Dr William Brooke O'Shaughnessy discovered that the blood of cholera victims suffered reduced amount of water and its alkali and saline. In the same year, Dr. Thomas Latta, a student of O'Shaughnessy's attempted a treatment by replacing the loss of substance directly delivery of saline solution. Dr Latta was known as "Father of Intravenous Therapy" performed the first IV procedure, giving a saline injection to a cholera patient where the patient cured from the dehydrated and cholera (22,24–27).

The innovation continues during the World War 1 and World War 2 after the discovery of blood group and Pyrogen (Infectious agent). Later, research invented plastic IV bag solution in late 1920 and until in 1957, Dr. Doherty invented and patented an alternative modernize IV catheter/cannula concept, a through–the-needle service that is well known today for design of

current PIVC. His design is the first catheter in the world to be made of sterilized and individually-packaged plasticized PVC (22).

USES OF PIVC FOR IV ROUTE MEDICAL TREATMENT

The type of VAD to be used on patient are affected by several factors. The medical staff will do the first screening to identify the condition and type of medical need of the patient. The patient can be someone who have high blood loss due to road accident, fluid depletion due to diarrhea, poisoning case, need for temporary haemodialysis, or an illness that require medication transfer into bloodstream regularly. Availability of oral medication and expected amount blood sample needed is also one of the factors involved to choose a correct VAD. In general, all type of VAD can supply medical fluid and take blood sample except for PIVC. PIVC function is only for administration of medical fluid.

The process of PIVC access start with insertion of the VAD into the venipuncture site at an angle around 25-30°. First blood flashback is observed in the flash chamber indicating the insertion is successful. The procedure continues with the visual confirmation of second blood flashback in the hollow plastic tube while the needle is being removed completely. After removing the catheter needle, the PIVC is positioned parallel to the skin with roughly at an angle of 5° before advance the cannula/catheter forward. The Luer extension set is then connected to the catheter/cannula to perform flushing with normal saline solution. The extension set later can be used for fluid medication purposes. The last process is to secure the PIVC by using IV securement dressing or device such as tape, bandage or splint.

Among all type of VAD, PIVC is one of the vital and common devices used in medical field around the world for IV line access. VAD used around 80% of hospital administration for administration of medical fluid direct into vein of patient either a PIVC or CVC (22) but about 70% of them received the PIVC (23).

The practice of fluid medical infusion through a PIVC access is commonly known as “drip”, “IV” or “IV therapy” is used for short-term of usage unlike other type of IV access such as Peripheral Inserted Central Catheter (PICC) or Port (28). Example situation use of IV therapy is during the patient is unable to receive medication orally due to vomiting, coma or unconscious during surgery (22,23). Other example including loss of water in blood of a dehydrated patient, where IV therapy is used as immediate approach to replace the fluid loss direct into the blood stream. Instead being called as a catheter, VAD for IV line access is sometime known as IV cannula or brannula. Even no IV therapy fluid is needed for the patients, the PIVC can be used for antibiotics administration such as dehydration, infection of bacteria, or gastroenteritis (29). As the term “Peripheral” is used, PIVC means the medication fluid is going in into the body, but not travelling far into the central line area such as the heart. PIVC commonly inserted into the vein by nurses, line team, or sometimes by the medical officers themselves. Other than PIVC such as PICC, or port can only be inserted by specially trained nurses, line team or physician that are the specialist catheter insertion staff.

PIVC DISLODGEMENT

Benchmarking Study for IV Dislodgement

Referring to Table I, overall intense study of PIVC failure only started roughly around 2013 and above. The lowest rate of dislodgement is 1.43% up to 66% (1,6,13,14,17–20,28,30,31). All studies all show no standard of benchmarking for data comparison and each IV failure analysis also have their own reason for the range created. For example, the studies from Lorente (2004), Thiagarajan (1997) and Jumani (2003) are only for CVC. Thiagarajan (1997) and Jumani (2003) targeted specifically only PICC. Therefore, it is confirm from other literature studies that PIVC do contributed greater dislodgement case and other complication than CVC such research from Mourea (2018) (13). Overall IV failure is also quite low of CVC compare to PIVC except

Table I: Case Study of Average IV Failure Complication

Case Study (Year)	Catheter Type for Case Study	No of sample, n	IV Failure Weightage from n	Dislodgement	Infiltration	Infection	Phlebitis	Occlusion	Sepsis
Thiagarajan et al. (1997)[a]	PICC (CVC)	441	29%	8%	-	-	-	7%	10%
Lorente et al. (2004)[b]	CVC	1608	-	1.43-6.58%	-	-	-	-	-
Jumani et al. (2013)[a, f]	PICC (CVC)	1807	20.8%	4.6%	3.0%	4.3%	1.2%	3.6%	-
Malyon et al. (2014)[a]	PIVC	456	24.8%	5%	14.3%	-	1.5%	-	-
Wallis et al. (2014)	PIVC	5907	36.6%	17.4%	-	-	12.6%	70%	-
Helm et al. (2015)[e]	PIVC	-	36-63%	3.7-50%	15.7-33.8%	0-2.2%	0.1-63.3%	2.5-32.7%	-
Rickard et al. (2015)	PIVC	1708	69%	-	-	-	-	-	-
Rickard et al. (2018)[c]	PIVC	1697	41%	9%	-	0.06%	25%	20%	-
Moureau et al. (2018)[d]	56.8% PIVC, 43.2% CVC	1561	68%	66%	-	-	-	-	-

[a]Paediatric only, [b]Accidental dislodgement study only, [c]Under controlled securement dressing/device and technique observation, [d]Survey study,
[e]Data from 1990 to 2014, [f]Data from 2003 to 2009, [g]Dislodgement study only (Accidental and Non-accidental)

for Malyon (2014) research, which perhaps due to small number of samples for PIVC insertion. Therefore, the low dislodgement case recorded by Lorente (2004) research is reasonable because the study is not only exclusively done on CVC, but also specifically for paediatric and accidental dislodgement only. That is why no other type of failure is recorded.

Significant of PIVC Dislodgement

Referring to Table I, Research from Mourea (2018) is the only one in the form of survey and its very comprehensive. The research not only illustrate the specific data of catheter dislodgement, but also its also provide information that most of the dislodgement is not reported. In a scale of five, it is found that for PIVC 19% strongly agreed (Level 5) that the dislodgement case is not reported and only 9% strongly agreed at the opposite site (Level 1). This information is not presented in any other literature conducted for this article. Apart of unreported dislodgement case, Alexandrous (2018) also shows that bad habit of poor PIVC documentation across 51% countries around he world. Therefore, this may explain the gap different of PIVC dislodgement in other literature study in Table I. Another 31% agreed (Level 4) that PIVC dislodgement is not reported. The same study by Mourea (2018) indicated that 68% of the 1561 patient subjected to dislodgement case that recorded to occurs either often, daily, or multiple times daily.

From 68% of VAD failure case, 80% are caused by confused patient. 74% of the failure case also related to the VAD being removed physically by the patients. It is also noted that among all type of VAD, short PIVC contributes highest rate of dislodgement case up to 97%. Among this 97% of PIVC failure cases, 20% medical personal agreed that the case to be very often to occur. Dislodgement of PIVC also rated up to 65% by poor IV securement and dressing. The common securement and dressing being used are tape, bandage and splint (1,2,13). Patients health care also halted, and medication fluid treatment delayed putting patient at 95% risk out of all dislodgement cases. Comparing some literature studies as in Table I, shows the IV failure occur minimally at around 25% for every 450 patients. The study also confirmed the high rate of dislodgement case as conducted by high number of sample study by Rickard (2015). Dislodgement case is still recorded even the amount of sample is small such as the study conducted by Malyon (2014).

PIVC Dislodgement for Paediatric Case

There is no specific study yet that validate any significant distinction dislodgement of PIVC of adult and Paediatric. However, some literature discussed the difficulties involved in PIVC insertion for Paediatric. For special patient such Paediatric, first attempt have higher failure rate compare to adult patient (40-50% fail on first attempt) and even the insertion is successful, the tendency of dislodgement is very high indicate crucial need to avoid multiple PIVC insertion to Paediatric patient (1). Paediatric patient is known to have low vein visibility that give hard time to medical staff to locate for venipuncture point and multiple staff involved to have the PIVC inserted successfully (5). Other literature supported that Paediatric's vein access is much more difficult and higher compilation (33%) when comparing to adult patient (26%) such as bruise and swelling at venipuncture point, therapy fluid leaking and dislodgement (9,15,33,34).

Medical Staff Factor Related to PIVC Dislodgement

Some studies also noted some other important factor related to IV securement device efficiency factor is visibility of venipuncture site. Medical staffs able to save more time by improving venipuncture site visibility for early sign of PIVC dislodgement or other compilation. Thus, it can reduce waste of time replacing securement and dressing (2). Using device does show a good and fast result to identify the vein especially difficult visibility of vein such as by using VeinViewer. However, the advance of medical device is only proficient with a complete and efficient training to the medical staff (34). Another concern that might raise is the extra cost for the procedure. After, knowledge and properly trained medical staff does affect the successful of first PIVC insertion and securement technique. Medical staff may have different experience and development their own technique to secure the PIVC dislodged. While Shamsuddin (2012) proved that a knowledgeable medical staff provide better IV infusion preparation, medical fluid administration, IV securement and create less adverse of PIVC including dislodgement (35).

PIVC SECUREMENT DRESSING/DEVICE

Conventional Practice

To secure the PIVC in place, the most common type of securement is by using sticky tape procedure. There are cases where the PIVC need to have extra securement such as by using splint or wrap with bandage. Some PIVC product have a plastic wing extended for better securement and increase tape support on venipuncture site. A good technique of dressing and securement can reduce the PIVC degree of freedom and preventing intravenous venipuncture site issues such as dislodgement, infiltration, infection or phlebitis (1).

Securement of IV device not only applied to PIVC but to other type of line or catheter as well (16). The use of just tape is most commonly used to secure the PIVC in place (1). Although using the tape is the faster and easier way to be used, it is not really an ideal item to be used as it's still subjected to dislodgement of PIVC especially if the patient sweat a lot.

Therefore, sometimes an extra device is needed to secure the PIVC is place such as wrap with bandage.

Bandage is usually used for Paediatric patient where the patient pulls the PIVC by themselves due to feeling of uncomfortable foreign object inserted into their body. Although bandaging is a good approach, it is not recommended due to visibility problem to monitor the venipuncture site for early detection of compilation (2). A good technique and practice can lead a good result of decreasing dislodgement cases. The setback is that bandage suffocate the patient's skin and if the patient sweat a lot it will lead to another compilation such as rash or redness problem.

There are cases where splint is used instead of bandage to completely immobilize the patient's venipuncture site. Splint can lead to redness along the splint edge, itchiness, and uncomfortable restrict movement especially Paediatric of elder patient.

Basis for Alternative IV Securement Dressing/Device
Current conventional method of IV securement still doesn't provide a good confidence level of successful result and some may lead to several other problem as discussed in the problem statement. Therefore, new alternative IV securement device is invsented such as the transparent type dressing, adhesive anchor type, and plastic shield type is designed to promote better stabilization and securement of PIVC on the venipuncture site. However, the efficacy of these new type of securement devices is also debatable as there is still no clear formal scientific research is being done yet and only relying on empirical data (23,28,36).

In the past few years, several continuous innovation products emerge in the market to counter setback of IV therapy compilations by having an IV securement device that can act as an extra protection and further increase the securement of PIVC. Nowadays a few alternative IV securement products penetrate the market with different securement method. One of the main reasons for the emerging of these alternative securement devices is due to social culture and value for money on current trend, thus a new science solution and methodology is born. These devices can be categorized into 3 parent groups (36):

1) Transparent Dressing:
The principle of this type of product is to have a transparent tape on venipuncture site when applied. Some products have an extra frame around the tape to increase securement of PIVC at the venipuncture site.

2) Adhesive Anchor:
An adhesive part usually in the form of pad is integrated with the PIVC part itself such as under the wing or the hub of the PIVC as a single product. Some other adhesive anchor product come in separate package, but the anchor still has can integrate with the PIVC for the securement purpose.

3) Plastic Shield:
Providing a plastic cover on top of PIVC to protect the venipuncture site from any form of hit or impact. The cover not only protect the venipuncture site but also to protect the whole PIVC area itself.

Efficacy of Alternative IV Securement Dressing/Device
Even for among the three categories of IV securement as mentioned by Hanchet (1999), either three of them have undergo a formal scientific research for their efficiency whereby the product supported solely on empirical data. Except for adhesive anchor type securement is being supported by both empirical data and quasi-science studies which only invested by small amount of firm or company (36). Frankly, majority of IV securement device relying on empirical data to provide confidence level of their product's efficacy. More literature studies shows that there a lack of studies of solution for optimum IV securement method and there are several reasons behind it such as patient categories limitation especially for Paediatric (32).

Although some literature shown improvement of PIVC failure rate, there is no formal comparison between different type of IV securement product yet (23,32,37) and studies shows that even with some improvement, there is an unwanted continuing problem arise and dislodgement case still occur at a high rate (13). The product comparison is still unclear with no proper scientific method to prove the product's efficacy, common use and even risk of good standard bias (28) and full day monitoring the IV securement device or dressing also seems impractical.

FREQUENCY OF PIVC USAGE

The main objective analysis of PIVC dislodgement is not only to study the countermeasure the adverse complications. Concurrently, three other important objectives also viewed as necessary need; to avoid unnecessary loss of good PIVC, to avoid extra work of medical staff for new PIVC insertion, and to avoid stress on patient receiving PIVC insertion. The effect is very significant because not only the use of PIVC is worldwide, but also one of the most common medical device at around 70% (22,23). Range use of PIVC is between one billion to two billions worldwide (30,37,38).

In United State of America (USA) alone, 300 millions of PIVC usage is estimated per year (4,6,19). A cost range of USD28-35 is estimated for the first success insertion of PIVC only. While PIVC is frequently used in USA even in acute care, the device is rarely used in Australia (37). However, Australia is also recorded as highest multiple venipuncture sites selection by Alexandrou (2018)(30). Although no literature discussed about average cost per PIVC, it can easily predict that the loss cost of good PIVC is very high considering the rate of PIVC failure in Table

I.

Perhaps the greatest fear is that the number of PIVC dislodgement increase around the world as the number hospital and clinical services increase around the world. Choosing Asian country's Malaysia as for example. As in other country in the world, Malaysia also subjected to high use of PIVC in the hospitals. The calculation to predict the frequency usage of PIVC can be calculated based on the number of hospital beds in a country. In Malaysia hospital, the number of bed from year 2012 to 2016 is illustrated in Fig. 1 (Source: https://www.statista.com/statistics/794868/number-of-beds-in-public-and-private-hospitals-malaysia/ - Revised from 26/6/2019).

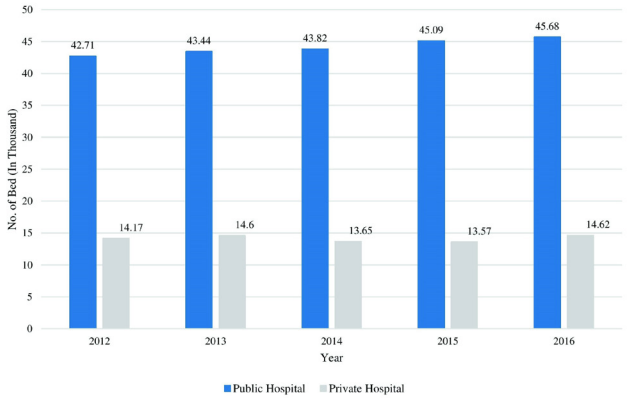

Figure 1: Number of Bed in Malaysia Hospital_2012-2016

The graph in Fig. 1 indicate that there is a trend of increasing number of beds in Malaysia hospital for both public and private hospital. This is due to increasing budget from Malaysia Government and improvement of Malaysia healthcare industry. Besides, Malaysia was awarded as the "Best Country for Healthcare" from 2015 to 2017 by International Living and awarded as "Top Asian Country for Retirement" in 2018 (Source: https://says.com/my/lifestyle/medical-travel-malaysia - Revised from 26/6/2019).

In summary, the number of bed available in Malaysia hospital is approximately at 60,000 units. In Fig.2, it is also noted that from Clinical Research Centre shows that the percentage of Bed Occupancy Rate (BOR) in Malaysia (Source: http://www.crc.gov.my/nhsi/charts/malaysia_bor.php - Revised from 26/6/2019) is roughly 71% for public hospital and almost 59% for private hospital in 2011 to 2013. Fig. 2 also indicated that the overall BOR for both sectors is almost at 67.5% from 2011 to 2013 with an increasing trend of occupancy rate from both sectors. Therefore, for 2019 the expected BOR for average of both sectors is possible to be at 70% from current known number of hospital bed in Malaysia.

The expected number of usage of PIVC is 70% (23) of the total number of bed in Malaysia hospital in both public and private sector. Considering the expected BOR to be at 70% in 2019, therefore the final number of

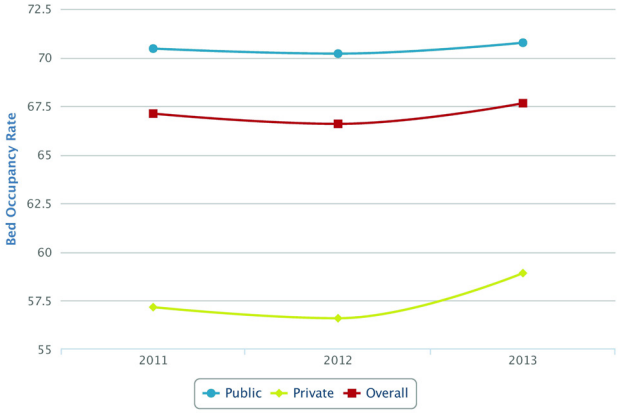

Figure 2: Bed Occupancy Rate in Malaysia Hospital 2011-2013

predicted usages of PIVC per day can be up to 30,000 units (maximum approximation) for 2019 as shown in Table II. Considering high frequency usage of PIVC, a small percentage of dislodgement or other failure could bring a lot of loss in certain amount of time.

Table II: Approximation Calculation of PIVC in Malaysia

	No. of Bed
Total No. of Bed	60,000
Bed Occupancy Rate (70%)	43,400
Expected Intravenous Treatment (70%)	30,380
Round Off Total (Per Day)	30,000

THE NEEDS OF PIVC NEW INVENTION OF SECUREMENT DEVICE

PIVC is an essential medical device used worldwide but the rate of failure of is staggering up to 69% under IV therapy session (6,13,50-54). An intensive research studies by and Moureau et. al (13) shows that the dislodgement case is one of the major contributions of PIVC failure. The research also supported previous studies by Malyon et. al (1) and Rickard et. al (23) where both researchers also noted that by adding alternative IV securement devices and methods also doesn't show significant reduction of dislodgement (38%-57%) on all type IV access device. Monitoring PIVC site 24 hours to avoid dislodgement is also challenging for both medical staffs and guardian. Paediatric patients have high tendency to pull out the PIVC due to pain or uncomfortable feeling on the venipuncture site. The unpredicted behavior of Paediatric patient leads to higher potential of dislodgement and multiple IV access attempts (2).

As PIVC access failure, patients also are frustrated with pain, discomfort or distressed that make them feel more concern of maintaining PIVC on venipuncture site than insertion of PIVC (15). Dislodgement of PIVC also required medical staff to restart whole IV access again which affects time and staff working productivity. Relocating new venipuncture site is rated up to 94%

for inconveniently affected the medical staff's work load and time especially related to Paediatric patients. Thus, some hospitals have the policy to not allowing disconnection of IV tubing even for visiting bathroom (13,23). Another main challenge of PIVC dislodgement is the increase of medical cost during PIVC replacement devices, adding more tape or additional securement devices. If half of PIVC failure cases are avoided, it can contributed a significant budget improvement (13). Other than dislodgement, other complications that are associated with are bleeding, occlusion, infection and phlebitis (18,23,28,32).

Although with an approach of better alternative securement device, Ya et. al (2) realized that medical staff willingness to convert different practice from conventional IV securement method is not always welcomed. Previous study by Major et. al (9) shows that it's hard for medical staff to get used for a new method especially related to common practice that already implemented to them since their studying time. Introduction of new innovation device/technique can be rejected although it is can proved result of reducing PIVC complication (2,9).

Due to this matter, an innovation approached is needed for an alternative cost-effective device to cater the PIVC securement from dislodgement.

IMPROVEMENT OF PIVC DESIGN CRITERIA

According to the data and literature research discussed, it is becoming clear that the short PIVC usage still need for a stability enhancement protocol. The discussion also provides clear and vivid prove that the proper scientific research on the PIVC securement is still needed, suggesting the PIVC securement method nowadays is actually far to be considered as "standard". Based on the author review, securement of the PIVC need a new "standard" aside of improving securement method. These are the field of improvement suggested that can be studied further:

1) PIVC Insertion Method:
On the main reason for PIVC to be unsecured or dislodged is related to the pain anxiety of the patient itself. The most affected patient is Paediatric with the most highest failure rate for first PIVC insertion compare to other (15). Therefore, PIVC solution related to nanotechnology for drug delivery can developed to ease the patient pain and provide comfortability to the patient. Theoretically, the tendency for the anxiety and patient to remove the patient by force can be reduced.

2) Adhesive Property:
The challenge for the adhesive part is there is a lot of contradiction involved. For example, the medical tape protocol tape todays is already economic. The medical tape is made of paper or cotton based designed to be breathable, thus bring less skin complication. However, the breathable properties lead to other problem such as adhesive properties is not strong enough or bacteria infection due to ease water contact. The Infusion Nurses Society (INS) 2016 Standard of Practice (39) also mentioned in the Standard 39 to have visual inspection and prevent water contact at venipuncture site for avoid contamination. Therefore, a new research can be conducted to find the alternative adhesive property for the PIVC fundamental securement. Conjunctionally, INS also already stated suture and medical tape is not an effective alternative.

3) New VAD Standard:
A lot of research already done and proved the VAD used today is not effective with lack of proven scientific research. Interestingly, from the comprehensive research by Alexandrou et. al (30) in 2017 conclude that the PIVC used on flexion area has the most problematic symptoms and most inconsistence securement method across 51 countries. Guideline for PIVC management also not standardized across rural and urban hospitals. The VAD also need to support the flexion area and maintain medication patency as proposed by the INS 2016 (39). Researchers and engineers need to come up with a bold and new standard for VAD design that can cater all the needs around the world. The VAD should also base on scientific research and according to medical staff requirement (customer demand) rather than a VAD without need by users. Aside of PIVC and VAD, the whole IV therapy medication system perhaps can be redesigned into an alternative and improved standard. The suggestion is raised to do the vary standard brand and design between PIVC and VAD to integrate. The VAD alternative design should also comply with a better and redefined policy and PIVC procedure.

RECOMMENDATION

From researcher's position, more research is needed in a standardized study group. As for example some data are based on the frequency used of PIVC in a certain amount of days and some based on number PIVC used. The clinical study specifically on PVC dislodgement is relatively quite low especially survey study based on medical profession perspective that is very valuable. The data are very important as a set of benchmarking to evaluate all reasons of dislodgement. Suggested criteria for the research study group is to include venipuncture site of PIVC, skin condition of patient, the cannula gauge sizes, age of patient (adult or paediatric), and even gender. Quality of PIVC is also not mentioned by the literatures that may actually affected the overall PIVC failure including dislodgement. For example, study by Alexandrou (2018) does provide comprehensive usage of PIVC across several countries but did not focus on type of IV failure occurred. The possibility of a region or country contributed to different level of dislodgement due to different healthcare services an important information

to be added. The reason for the suggested group for research study is because the some of the categories shows distinct dislodgement result. Moreover, only a few researches are available to be used as benchmarking for further case study or research. Even the definition of "dislodgement" is also varying across the literatures. The term "dislodgement" is inconsistently related to accidental dislodgement, both accidental and non-accidental removal, IV therapy premature completion, or PIVC removal due to complication (13,19,30,31).

For dislodgement of CVC is clearly shows relatively small compare to the PIVC. However, the dislodgement and related complication of CVC is also need to be taken care to be avoided. These data are very important to have deeper understanding of the fundamental factors related to dislodgement of PIVC. The data also is very valuable for a better development of PIVC, more efficient IV securement dressing/dressing, avoidance of dislodgement and associated complications. Moreover, more survey study needs to be done as well to analyze dislodgment data from medical staff point of view instead of relying on actual clinical data. Study on the securement technique and better approach is also a vital need. This is because aside of dislodgement, unsecure manipulation of the PIVC movement on the venipuncture can make the hollow tube of the PIVC tear the inside vein can also caused other IV complication such as bleeding, infiltration and infection (7,12,13,20).

As suggested by the author, more research and development need to be raised based on the user's demand. A proper scientific research need to focus on the real fundamental problem and comply with the INS Standard of Practice (39) for a better solution. Although PIVC has the most highest rate of stability failure compare to CVC, is also noted that CVC failure also lead to the same complication as PIVC failure. The collaboration for securement risk solution should include a new alternative and standard PIVC policy and protocol between all manufacture of peripheral medical devices.

CONCLUSION

The literature study showed every research has its own specific objective that is hardly used as a benchmarking for deeper understanding of PIVC dislodgement and other complication. This is because there are a lot of factors that is still unclear since between some literatures showed quite a noticeable gap for dislodgement case. Even though the literatures showed high rate of failure related to PIVC dislodgement which is staggering up to 69%, less research studies has been conducted in solving this issue. Hence, an innovative study needs to be conducted in designing a new securement device by following the design requirement which suited with the medical practitioner. The improvement of design criteria also need to be explored such as PIVC insertion method, adhesive property, and new VAD standard in ensuring the new development of securement design will reduce the possibility of dislodgement issue.

ACKNOWLEDGEMENT

The author would to express utmost gratitude to Department of Aerospace Engineering, Faculty of Engineering Universiti Putra Malaysia for supported this article work under GP-IPM grant, 9675000.

REFERENCES

1. Malyon L, Ullman AJ, Phillips N, Young J, Kleidon T, Murfield J, et al. Peripheral intravenous catheter duration and failure in paediatric acute care : A prospective cohort study. 2014;(August):602–8.
2. Ya E, Lim P, Yuit C, Wong W, Kek LK, Nursing M, et al. Improving the Visibility of Intravenous (IV) Site in Pediatric Patients to Reduce IV Site Related Complications – An Evidence-based Utilization Project. J Pediatr Nurs. 2018;41:e39–45.
3. Hoste EA, Maitland K, Brudney CS, Mehta R, Vincent JL, Yates D, et al. Four phases of intravenous fluid therapy: A conceptual model. Br J Anaesth. 2014;113(5):740–7.
4. Özkula U, Ilzhasenekler A, Kurtoğlu 3elik G, Tanrıverdi F, Pamukçu Günaydın G, Ergin M, et al. Tissue adhesives to secure peripheral intravenous catheters: A randomized controlled trial in patients over 65 years. Turkish J Emerg Med. 2019;19(1):12–5.
5. Sou V, McManus C, Mifflin N, Frost SA, Ale J, Alexandrou E. A clinical pathway for the management of difficult venous access. BMC Nurs. 2017;16(1):0–7.
6. Alexandrou E, Ray-Barruel G, Carr PJ, Frost SA, Inwood S, Higgins N, et al. Use of Short Peripheral Intravenous Catheters: Characteristics, Management, and Outcomes Worldwide. J Hosp Med. 2018;13(5):1–7.
7. Jacinto AK de L, Avelar AFM, Wilson AMMM, Pedreira M da LG. Phlebitis associated with peripheral intravenous catheters in children: study of predisposing factors. Esc Anna Nery - Rev Enferm. 2014;18(2):220–6.
8. Samuel S. D, D.A. G, D. C, M. H. Intravenous therapy: A review of complications and economic considerations of peripheral access. J Infus Nurs. 2012;35(2):84–91.
9. Major TW, Huey TK. Decreasing IV Infiltrates in the Pediatric. 2016;42(1):14–21.
10. Fasugba O, Koerner J, Mitchell, Gardner BG, Gardner A, Mitchell B, et al. Infection Prevention: Peripheral Intravenous Catheter Assessment and Care. J Hosp Infect. 2017;24(8):2017.
11. Miliani K, Taravella R, Thillard D, Chauvin V, Martin E, Edouard S, et al. Peripheral venous catheter-related adverse events: Evaluation from a

multicentre epidemiological study in France (the CATHEVAL project). PLoS One. 2017;12(1):1–17.
12. Salgueiro-Oliveira A, Parreira P, Veiga P. Incidence of phlebitis in patients with peripheral intravenous catheters: The influence of some risk factors. Aust J Adv Nurs. 2012;30(2):32–9.
13. Moureau N, Crni RN. Impact and Safety Associated with Accidental Dislodgement of Vascular Access Devices : A Survey of Professions , Settings ,. J Assoc Vasc Access. 2018;23(4):203–15.
14. Ketan Jumani, Sonali Advani, Nicholas G. Reich, Leslie Gosey AMM. Risk Factors for Peripherally Inserted Central Venous Catheter Complications in Children. JAMA Pediatr. 2014;167(5):429–35.
15. Cooke M, Ullman AJ, Ray-barruel G, Wallis M, Corley A, Rickard CM. Not " just " an intravenous line : Consumer perspectives on peripheral intravenous cannulation (PIVC). An international cross- sectional survey of 25 countries. 2018;1–18.
16. Duwadi S, Zhao Q, Singh B. Peripherally inserted central catheters in critically ill patients e complications and its prevention : A review. Int J Nurs Sci. 2019;6(1):99–105.
17. Lorente L, Henry C, Martнn MM, Jimйnez A, Mora ML. Central venous catheter-related infection in a prospective and observational study of 2 , 595 catheters. 2005;9(6).
18. Thiagarajan RR, Ramamoorthy C, Gettmann T, Bratton SL, Objective A. Survey of the Use of Peripherally Inserted Central Venous Catheters in Children. 1997;99(2).
19. Wallis MC, McGrail M, Webster J, Marsh N, Gowardman J, Playford EG, et al. Risk Factors for Peripheral Intravenous Catheter Failure: A Multivariate Analysis of Data from a Randomized Controlled Trial. Infect Control Hosp Epidemiol. 2014;35(1):63–8.
20. Helm RE. Accepted but Unacceptable: Peripheral IV Catheter Failure. J Infus Nurs. 2019;42(3):149–50.
21. Arun O, Oc B, Gunduz E, Oc M, Duman A. Fracture of an intravenous cannula in the vein due to reinsertion of the guide needle: A Case Report. Journal-Cardiovascular Surg. 2014;2(2):28.
22. C W, P W, M P. Intravenous therapy. Postgrad Med J. 2004;(August 2003):1–6.
23. Rickard CM, Marsh N, Webster J, Playford EG, Mcgrail MR, Larsen E, et al. Securing All intraVenous devices Effectively in hospitalised patients — the SAVE trial : study protocol for a multicentre randomised controlled trial. 2015;1–7.
24. MacGillivray N. Dr Thomas Latta: The father of intravenous infusion therapy. J Infect Prev. 2009;10(SUPPL. 1):8–11.
25. Rivera AM. The history of peripheral intravenous catheters : How little plastic tubes revolutionized medicine. Acta Anжsthesiologica Belgica. 2005;271–82.
26. Barsoum N, Kleeman C. Now and then, the history of parenteral fluid administration. Am J Nephrol. 2002;22(2–3):284–9.
27. Parampreet Kaur CR, Gregory S. Domer KRG. Dangers of Peripheral Intravenous Catheterization: The Forgotten Tourniquet and Other Patient Safety Considerations. Intech. 2016;i(tourism):13.
28. Marsh N, Webster J, Mihala G, Rickard CM. Devices and dressings to secure peripheral venous catheters to prevent complications (Review). Wiley. 2015;(6):1–56.
29. Vanderkooy TO, Tucker H. The Safety of Discharge of Pediatric Patients With Peripheral IV Catheter in Place Until Time of Follow-Up. Ann Emerg Med. 2013;62(4):S70–1.
30. Alexandrou E, Ray-Barruel G, Carr PJ, Frost SA, Inwood S, Higgins N, et al. Use of Short Peripheral Intravenous Catheters: Characteristics, Management, and Outcomes Worldwide. J Hosp Med. 2018;13(5).
31. Lorente L, Huidobro MS, Martнn MM, Jimйnez A, Mora ML. Accidental catheter removal in critically ill patients : a prospective and observational study. 2004;8(4):229–33.
32. Ad RH, Mph MW, Hill EK, Rn CH. Securing Pediatric Peripheral IV Catheters — Application of an Evidence-Based Practice Model 1. J Pediatr Nurs. 2011;26(2):143–8.
33. Candice Heltz. Improving Peripheral IV Safety by Maximizing Ability to Assess and Secure Lines. J Pediatr Nurs. 2009;24(2):e10–1.
34. Kim MJ, Park JM, Rhee N, Je SM, Hong SH, Lee YM, et al. Efficacy of VeinViewer in pediatric peripheral intravenous access: A randomized controlled trial. Eur J Pediatr. 2012;171(7):1121–5.
35. Shamsuddin AF, Shafie SD. Knowledge of Nurses in the Preparation and Administration of Intravenous Medications. Procedia - Soc Behav Sci. 2012;60:602–9.
37. Rickard CM, Marsh N, Webster J, Runnegar N, Larsen E, Mcgrail MR, et al. Dressings and securements for the prevention of peripheral intravenous catheter failure in adults (SAVE): a pragmatic , randomised controlled , superiority trial. Lancet. 2018;392(10145):419–30.
38. Rivera AM, Strauss KW, Van Zundert AAJ, Mortier EP. Matching the peripheral intravenous catheter to the individual patient. Acta Anaesthesiol Belg. 2007;58(1):19–25.
39. Gorski L, Hadaway L, Hagle ME, McGoldrick M, Orr M, Doellman D. Infusion Therapy Standard of Practice. J Infus Nurs. 2016;39.
40. Idemoto BK, Rowbottom JR, Reynolds JD, Hickman Jr RL. The AccuCath Intravenous Catheter System with retractable coiled tip guidewire and Conventional Peripheral Intravenous Catheters: a prospective, randomized, controlled comparison. Journal of the Association for Vascular Access. 2014 Jun;19(2):94-102.
41. Kokotis K. Cost containment and infusion

services. Journal of Infusion Nursing. 2005 May 1;28(3S):S22-32.
42. Wolosin RJ. Largest study of patient satisfaction ever conducted. The Press Ganey Satisfaction Report. 2003 Aug;7:2-4.
43. Danek G, Kilroy IV R. CQI study: impact of a vascular access planning algorithm on patient outcomes. Friday's Focus Hospital Newsletter at Shands (University of Florida). 1998 Apr;5:1-5.
44. Hadaway L. Short peripheral intravenous catheters and infections. Journal of Infusion Nursing. 2012 Jul 1;35(4):230-40.
45. Hadaway L. Escalation of vascular access devices. InAssociation for Vascular Access Annual Scientific Meeting 2011 Oct 3.
46. Schears GJ. Summary of product trials for 10, 164 patients: comparing an intravenous stabilizing device to tape. Journal of Infusion Nursing. 2006 Jul 1;29(4):225-31.
47. Frey AM, Schears GJ. Why are we stuck on tape and suture?: A review of catheter securement devices. Journal of Infusion Nursing. 2006 Jan 1;29(1):34-8.
48. Kokotis K. Vascular access case management and clinical pathways: the role of the IV therapist. Journal of Vascular Access Devices. 1999 Dec;4(4):22-7.
49. Meyer BM. Broadening infusion specialization as an adjunct to organizational sustainability. Journal of Infusion Nursing. 2014 Jan 1;37(1):44-54.
50. Hawthorn A, Kleidon T, Larsen E, Marsh N, Marshall A, Ray-Barruel G, Sinclair S, Slaughter E, St John A, Taliaferro K. Peripheral intravenous catheters: A review of guidelines and research (2019).
51. Bausone-Gazda D, Lefaiver CA, Walters SA. A randomized controlled trial to compare the complications of 2 peripheral intravenous catheter-stabilization systems. Journal of Infusion Nursing. 2010 Nov 1;33(6):371-84.
52. Helm RE, Klausner JD, Klemperer JD, Flint LM, Huang E. Accepted but unacceptable: peripheral IV catheter failure. Journal of Infusion Nursing. 2015 May 1;38(3):189-203.
53. Marsh N, Webster J, Larson E, Cooke M, Mihala G, Rickard CM. Observational Study of Peripheral Intravenous Catheter Outcomes in Adult Hospitalized Patients: A Multivariable Analysis of Peripheral Intravenous Catheter Failure. Journal of hospital medicine. 2018 Feb;13(2):83-9.
54. Wallis MC, McGrail M, Webster J, Marsh N, Gowardman J, Playford EG, Rickard CM. Risk factors for peripheral intravenous catheter failure: a multivariate analysis of data from a randomized controlled trial. Infection Control & Hospital Epidemiology. 2014 Jan;35(1):63-8.
55. Royer T. Improving short peripheral IV outcomes: a clinical trial of two securement methods. Journal of the Association for Vascular Access. 2003 Dec;8(4):45-9.
56. Campbell C, Bowden T. Peripheral vascular access devices: care and maintenance. British Journal of Cardiac Nursing. 2011 Mar;6(3):132-40.
57. Keogh S, Flynn J, Marsh N, Higgins N, Davies K, Rickard CM. Nursing and midwifery practice for maintenance of vascular access device patency. A cross-sectional survey. International journal of nursing studies. 2015 Nov 1;52(11):1678-85.
58. Hawthorn A, Bulmer AC, Mosawy S, Keogh S. Implications for maintaining vascular access device patency and performance: Application of science to practice. The journal of vascular access. 2019 Sep;20(5):461-70.
59. Hadaway LC. Preventing and managing peripheral extravasation. Nursing2019. 2009 Oct 1;39(10):26-7.
60. Dychter SS, Gold DA, Carson D, Haller M. Intravenous therapy: a review of complications and economic considerations of peripheral access. Journal of Infusion Nursing. 2012 Mar 1;35(2):84-91.
61. Ray-Barruel G, Polit DF, Murfield JE, Rickard CM. Infusion phlebitis assessment measures: a systematic review. Journal of evaluation in clinical practice. 2014 Apr;20(2):191-202.
62. Tagalakis V, Kahn SR, Libman M, Blostein M. The epidemiology of peripheral vein infusion thrombophlebitis: a critical review. The American journal of medicine. 2002 Aug 1;113(2):146-51.
63. Catney MR, Hillis S, Wakefield B, Simpson L, Domino L, Keller S, Connelly T, White M, Price D, Wagner K. Relationship between peripheral intravenous catheter dwell time and the development of phlebitis and infiltration. Journal of Infusion Nursing. 2001 Sep 1;24(5):332-41.
64. Malach T, Jerassy Z, Rudensky B, Schlesinger Y, Broide E, Olsha O, Yinnon AM, Raveh D. Prospective surveillance of phlebitis associated with peripheral intravenous catheters. American journal of infection control. 2006 Jun 1;34(5):308-12.
65. Uslusoy E, Mete S. Predisposing factors to phlebitis in patients with peripheral intravenous catheters: a descriptive study. Journal of the American Academy of Nurse Practitioners. 2008 Apr;20(4):172-80.
66. Rickard CM, Webster J, Wallis MC, Marsh N, McGrail MR, French V, Foster L, Gallagher P, Gowardman JR, Zhang L, McClymont A. Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. The Lancet. 2012 Sep 22;380(9847):1066-74.
67. Zhang L, Cao S, Marsh N, Ray-Barruel G, Flynn J, Larsen E, Rickard CM. Infection risks associated with peripheral vascular catheters. Journal of infection prevention. 2016 Sep;17(5):207-13.
68. Bolton D. Improving peripheral cannulation practice at an NHS Trust. British Journal of Nursing. 2010 Nov 25;19(21):1346-50.

69. Dillon MF, Curran J, Martos R, Walsh C, Walsh J, Al-Azawi D, Lee CS, O'shea D. Factors that affect longevity of intravenous cannulas: a prospective study. QJM: An International Journal of Medicine. 2008 Sep 1;101(9):731-5.
70. Bolton D. Improving peripheral cannulation practice at an NHS Trust. British Journal of Nursing. 2010 Nov 25;19(21):1346-50.