



Central Venous Lines in Emergencies

Time for a New Approach

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EXECUTIVE SUMMARY

As many as five million central venous lines are placed in patients in the United States annually. Unfortunately, 15% of those patients will experience complications. Infection, sepsis, thrombosis and embolism are among the most common and more serious complications. Central line-associated bloodstream infections alone have a mortality rate as high as 20%. The costs associated with these complications are significant, as much as \$56,000 per episode. In light of the 2008 rules from the Centers for Medicare and Medicaid Services (CMS) that disallow reimbursement to hospitals for many iatrogenic conditions, many healthcare payors are increasingly reluctant to pay for central line complications and other preventable conditions. Therefore, the full cost of these complications now may fall solely on the hospital.

Central lines are time-consuming and costly. Despite some success from recent advances, complications remain a significant challenge. However, central line use, complications, and complication-related costs can be reduced through judicious use of alternative vascular access routes. In many cases central line complications are avoidable altogether. Inserting a central line merely to achieve vascular access is no longer necessary. A safer, more rapid and reliable alternative to vascular access is readily available in the new generation of intraosseous (IO) vascular access devices.

The American Heart Association's Advanced Cardiac Life Support (ACLS) guidelines, the National Association of Emergency Medical Services Physicians (NAEMSP) and the European Resuscitation Council (ERC) now recommend intraosseous access over central lines for cardiac arrest and other emergency situations when peripheral venous access is not easily attainable. Intraosseous vascular access offers practitioners a safe, rapid, and effective alternative to central lines that is easy to use and cost-effective. The safety profile of intraosseous access may provide hospitals with substantial savings potential through avoiding unnecessary central lines and the associated costs of complications. More importantly, intraosseous access offers the potential to save lives. Due to these advantages and a well-documented safety record, intraosseous access is now the standard of care for many medical providers who face vascular access challenges.



RECOMMENDATIONS

- Providers should avoid central line-related complications by using intraosseous vascular access as a bridge to central lines when strict compliance with practice guidelines is challenging or not feasible.
- Intraosseous access should be used as an alternative to central venous lines when peripheral venous access is difficult or impossible for medically necessary cases (e.g. cardiac arrest, drug overdose, and acute conditions of chronic illnesses when peripheral lines are problematic).
- Medical providers should use the intraosseous route when central line access is considered solely for vascular access.
- The intraosseous route should be used as the first line of access in emergency situations where rapid vascular access is required.
- Healthcare providers should implement use of a central line checklist whenever placing central lines.



INTRODUCTION

Central venous lines have been a mainstay of modern medicine for decades, widely used across all medical specialties from cardiology to oncology, from the emergency department to the intensive care unit. Central lines were first introduced in the early 1950s and used in military medicine for the treatment of battlefield casualties. They were adopted into civilian medical practice shortly thereafter. In the 1960s central lines were used to provide total parenteral nutrition and to directly measure blood pressure for hemodynamic monitoring. It is estimated that US healthcare practitioners place between 3.3 and 5 million central lines annually.^{1, 2, 3}

Despite their widespread use in medical care, central venous lines are associated with high rates of complications that include infection, hemorrhage, and thrombosis, among others. Complications of central lines have a high mortality rate – as high as 20% for catheter-related bloodstream infections – and are costly.⁴ The Centers for Disease Control and Prevention (CDC) estimated in 2002 each central line-associated bloodstream infection costs up to \$56,000 per episode.⁵ In addition, central line infections can add 7 to 14 days to a hospital stay.⁴

Due to increased attention to these statistics, reducing and preventing central line complications is now a priority for hospitals, healthcare payors, regulatory agencies, and other various healthcare organizations. The Joint Commission (TJC), which sets standards for many healthcare facilities, now requires hospitals to implement best practices to prevent central line-associated bloodstream infections, including avoidance of the femoral vein as an access site. The Institute for Healthcare Improvement (IHI), a non-profit group, identifies the reduction of central line infections as one of several key initiatives to reduce patient harm in healthcare settings. As further evidence, the Centers for Medicare and Medicaid Services (CMS) no longer reimburses hospitals for most central venous line complications and other preventable hospital-acquired conditions. Other healthcare payors are quickly following suit.

Many healthcare providers – especially those in emergency medicine – rarely see the downstream consequences and complications associated with central lines. This white paper provides relevant data for physicians and other healthcare providers on the types and associated costs of central venous line complications, summarized from the medical literature. The paper also briefly reviews current policy initiatives to prevent central line complications, including reductions achieved through strict adherence to recognized evidence-based guidelines. Finally, this paper addresses a new approach to avoid many central line complications through judicious use of intraosseous access as an alternative vascular access route, particularly in situations where strict infection control measures are not feasible.



COMPLICATIONS OF CENTRAL LINES

Over 35 types of central line-related complications have been reported in the literature.⁶ Many of these complications can be fatal. Major types of central line complications are listed in Table 1.⁶ Infectious and thrombotic complications are the most prevalent type, observed in as many as 26% of patients (Table 2).⁷

TABLE 1: Major Complications of Central Venous Lines

| SERIOUS OR FATAL | LESS SERIOUS |
|----------------------------------|---------------------|
| Infection and sepsis | Extravasation |
| Hemorrhage | Infiltration |
| Thrombosis | Edema |
| Embolism | Swelling |
| Pneumothorax | Persistent bleeding |
| Hemothorax | Catheter fracture |
| Cardiac perforation | Catheter occlusion |
| Cardiac arrhythmia | Thrombophlebitis |
| Lost guidewire | |
| Dislodgement of vena cava filter | |

Source: Silberzweig et al, *J Vasc Interv Radiol* 2003

TABLE 2: Incidence of Central Venous Line Complications

| TYPE OF COMPLICATION | INCIDENCE |
|----------------------|-----------|
| Infectious | 5-26% |
| Thrombotic | 2-26% |
| Mechanical | 5-19% |

Source: McGee and Gould, *NEJM* 2003



THROMBOTIC AND MECHANICAL COMPLICATIONS

Thrombosis. Thrombotic clots can form if the venous wall is damaged during catheter insertion. As many as two-thirds of patients with indwelling central lines of one week or more display catheter-related thrombosis in ultrasound images.⁴ The incidence of thrombotic complications in actual clinical practice is difficult to determine, with estimates ranging from 6.6% to more than 50%.^{4, 7} Thrombosis is more common with difficult catheter insertions and with inexperienced healthcare providers. Catheters placed in the subclavian vein appear to pose greater risk for thrombotic complications (Table 3).⁷

TABLE 3: Site-Related Complications

| ANATOMICAL SITE | COMPLICATION | INCIDENCE |
|------------------|--|------------|
| Femoral | Mechanical | 12.8-19.4% |
| | Thrombosis | 6.6-25% |
| | Hemorrhage (femoral or retroperitoneal) | 1.3% |
| Subclavian | Mechanical | .2-10.7% |
| | Thrombosis | 10-50% |
| | Pneumothorax | 1.5-2.3% |
| Internal jugular | Mechanical | 6.3-11.8% |

Sources: McGee and Gould, *NEJM* 2003, Merrer et al, *JAMA* 2001

An evidence-based review also found the femoral vein to be at high risk for catheter-related thrombotic complications.⁸ Thrombosis can be fatal if the clot dislodges from the vessel wall and enters the bloodstream. Additionally, thrombus formation dramatically increases the risk of infection. Thrombophlebitis, inflammation of the venous wall, can accompany thrombus formation.

Hemorrhage. Hemorrhage can occur as a result of venous or arterial puncture, either during the insertion process or if the catheter becomes malpositioned during use. Puncture of the vascular wall is more likely to occur if the catheter tip is perpendicular to the wall of the vein.⁴ This complication can be fatal for some patients.

Pneumothorax and Hemothorax. Pneumothorax, lung collapse due to puncture of the lung, and hemothorax, lung collapse due to blood pooling in the pleural cavity can occur for the same reasons noted above, i.e. malpositioning, and clinician inexperience. Pneumothorax is among the most frequent complications associated with the subclavian site. It can often be detected by radiographic confirmation after each catheter insertion.⁹



Embolism. Emboli are potentially fatal complications of central lines.¹⁰ Pulmonary embolism occurs when a thrombotic clot breaks free of the catheter tip or venous wall and is transported to the lung. Air embolism occurs when air is inadvertently introduced into the catheter or intravenous line, potentially causing vascular collapse. In catheter embolism, the catheter tip can break off and enter the vascular system, requiring a cardiac catheterization for removal. Catheter embolism is most often caused by product malfunction or poor clinical technique.

Other (non-infectious) Complications. Other mechanical complications are extravasation (leakage of fluid from the catheterized vein into the surrounding tissue) and infiltration (fluid from a dislodged catheter infused into the tissue). Guidewires for catheter insertion pose a hazard in this area.¹¹ Cardiac arrhythmia, a more serious complication, may be induced if the catheter guidewire enters the heart chambers stimulating cardiac muscle during insertion.¹² Guidewires can also get lost in the blood vessel, necessitating surgical removal. Special care in vascular access must be taken for patients with inferior vena cava filters, as catheter guidewires can dislodge the filter.¹³ Femoral vein access is not recommended for these patients.¹⁴

INFECTIOUS COMPLICATIONS

Infection is one of the most common complications of central venous lines. The CDC estimates that 250,000 patients develop central venous catheter-related bloodstream infections annually, with a mortality rate of up to 20%.⁵ More than half of bacteremia epidemics in healthcare settings can be traced to infections from venous catheters.¹⁰ Catheter-related infection is the third most common hospital infection according to the National Healthcare Safety Network (formerly known as the National Nosocomial Infections Surveillance or NNIS), following ventilator-associated pneumonia and urinary tract infections due to urinary catheters.¹⁵ Additionally, approximately 90% of bloodstream infections are due to central venous catheters.¹⁶

The reported incidence rates for central venous catheter-related infections vary widely, partially due to variations in the definition of infection. Up to 40% of hospitalized patients with central venous catheters develop some type of infectious complication.^{17, 18, 19} The infection rate is even higher in the intensive care unit (ICU), where more than half of all ICU patients have central venous catheters.^{18, 19}

The definition of infectious complications in these studies range from bacterial colonization of blood sampled from the catheter to clinical signs of infection and confirmation of systemic infection.²⁰ The CDC criteria for catheter-related infection are more rigid, requiring clinical signs of infection, positive blood culture from the catheter, and confirmed systemic infection.



Infectious complications of catheters are significant and costly problems in healthcare today. Rates of infection vary with the anatomical site for catheter insertion. Infection rates are typically higher for the femoral vein and the external jugular vein, although there is some disagreement in the medical literature regarding infection risk at the femoral site (Table 4).^{21, 22, 23} Published guidelines on reducing central line-related bloodstream infections by the CDC, IHI, TJC, and other organizations strongly recommend against the use of the femoral vein for central lines.^{5, 24, 25, 26}

TABLE 4: Site-Related Infections

| INSERTION SITE | INFECTION INCIDENCE |
|------------------|---------------------|
| Subclavian | 7-15% |
| Internal jugular | 12-28% |
| External jugular | 22-47% |
| Femoral | 34% |

Source: Reed et al. *Intensive Care Med*, 1995

A literature review of more than 100 articles on catheter-related infection identified several causes of infection.²⁷ The most common source of bacterial contamination is the skin or the catheter hub.²⁷ Bacteria migrate from the skin down the body of the catheter.²⁷ Lack of maximal sterile barriers and proper hand hygiene during catheter placement are significant risk factors for infection.^{5, 17, 25, 28, 29, 30} One study found that catheter-related infections increased six-fold with the use of minimal sterile barrier technique (sterile gloves and small drape) compared to maximal sterile barrier (cap, mask, sterile gown, gloves for the healthcare provider, and full body sterile drape for the patient).^{26, 31}

The length of time the central venous catheter is left in the body is another important factor in infectious complications. The catheter should be removed within 24 hours if inserted under conditions with less than optimal sterility. Even with optimal insertion techniques, the risk of infection increases by 2 to 5% if the catheter is left in for up to seven days and increases by 10% if the catheter is left in for more than a week.¹⁷ The risk of infection also increases substantially if a thrombus forms at the tip of the catheter.²¹ Other sources of bacterial contamination are three-way stopcocks (especially in parenteral feeding), contaminated intravenous fluid, and airborne bacteria.

Patient factors are important as well. Prolonged hospitalization increases the risk of catheter-related infection,²⁵ as well as underlying disease or infection, malignancy, neutropenia and immunosuppressive treatment. Infection risk increases as much as 200% or more if the patient is in shock, in the ICU, on a ventilator, or receiving invasive hemodynamic monitoring or total parenteral nutrition.^{17, 25}



COSTS OF CENTRAL LINE COMPLICATIONS

Complications of central lines are costly. As many as five million central lines are inserted annually by US healthcare providers and more than 15% of patients with central lines will experience complications.⁷ Prolonged hospitalizations and significant medical costs often result.^{5, 25, 32} In 2002 the costs due to infectious complications alone were estimated at \$296 million to \$2.3 billion annually.⁵ The CDC estimated the cost per case of catheter-related infection in the range of \$34,500 to \$56,000.⁵ Other studies calculated costs as high as \$29,000 and \$40,000 per catheter-related infection.^{33, 34}

Many of these costs are borne by the hospital or healthcare provider. CMS, as well as insurance companies and other payors, are now disallowing payment for hospital-acquired infections resulting from the use of central lines. As noted previously, infectious complications alone can add one week or more to a hospital stay.^{17, 32} The prolonged length of stay due to infectious complications decreases the number of beds available for new admissions.

PREVENTING INFECTIOUS COMPLICATIONS

While medical literature reports multiple efforts to reduce central line complications, this paper will address a few of the most common discussions.

Ultrasound. Ultrasound-guided central lines are advocated by some experts in an attempt to decrease the risk of insertion errors. Although research results are mixed, some of these experts predict the use of ultrasound (for central line placement) will become more prevalent in medical practice.^{35, 36} Unfortunately many practicing physicians are not skilled at using ultrasound for central line placement. Ultrasound adds several minutes to catheter placement and requires additional resources in personnel and equipment. Ultrasound also increases the overall cost of a central line procedure.

Femoral Lines. Central venous lines are often placed in the femoral vein in patients in the emergency department, despite the accompanying high risk of complications. This is due to the need for very rapid vascular access in urgent or life-threatening situations.³⁷ The CDC, IHI TJC, and other organizations strongly recommend against the use of the femoral vein for central lines.^{5, 24, 25, 26, 38, 39}

Identification of Best Practices. The CDC has issued guidelines to reduce catheter-related infections, drafted in collaboration with 12 medical professional societies.⁵ In 2008, the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA) jointly issued practice recommendations to prevent central line-associated infections in hospital settings.²⁵ The Institute for Healthcare Improvement (IHI) has sponsored several process improvement initiatives to reduce central line-related infections in hospitals, culminating in the central line bundle.^{26, 40, 41} Department of Veterans Affairs researchers have published a review



article on preventing central line complications in the New England Journal of Medicine.⁷ These guidelines and practice recommendations all follow the same key basic principles for infection control. Table 5 provides a summary of catheter-related complications and preventative interventions.^{7, 25, 38}

TABLE 5: Interventions to Prevent Central Line Complications

| COMPLICATION TYPE | INTERVENTION TO DECREASE COMPLICATIONS |
|--------------------------|--|
| Infection | • Catheters with antimicrobial coatings |
| | • Use of subclavian anatomical site |
| | • Maximal sterile barriers for insertion |
| | • No antibiotic ointments |
| | • Regular disinfection of catheter hubs |
| | • No routine catheter changes |
| | • Chlorhexidine sponges and less frequent dressing changes |
| | • Prompt removal of unnecessary catheters |
| Thrombosis | • Use of subclavian anatomical site |
| Mechanical complications | • Identify patients at risk for difficult catheterization (includes skeletal deformity, scarring or prior surgery) |
| | • Healthcare provider experienced in central venous catheterization (>50 catheterizations) |
| | • Avoid femoral vein, if possible |

Source: McGee et al. *NEJM*, 2003; Marschall et al. *Inf Contr Hosp Epid* 2008; Timsit et al. *JAMA* 2009

INITIATIVES TO REDUCE CENTRAL VENOUS LINE COMPLICATIONS

Reducing central line complications is a priority for many healthcare providers as a result of several initiatives from major healthcare organizations.

POWERFUL FINANCIAL PENALTIES

As mentioned previously, CMS no longer pays for most complications of central venous line use. Vascular catheter-associated infections are included on their list of 10 “no-pay” hospital-acquired conditions for fiscal year 2009.⁴² Private insurance companies are also adopting this “Pay for Performance” approach, placing the financial liability for many preventable hospital-acquired conditions on hospitals and other healthcare providers.



ENFORCEMENT OF BEST PRACTICES

The Joint Commission, as a part of its 2009 National Patient Safety Goals, requires hospitals to implement best practices to prevent catheter-associated bloodstream infections.²⁴ This requirement features a 13-point implementation plan that includes vigilant monitoring of infection rates, healthcare worker and patient education, standardized protocols and checklists, and use of maximal sterile barriers for catheter insertion. TJC cautions against use of the femoral vein and recommends that central lines be evaluated daily with removal of central lines that are no longer necessary.

The AHA's Advanced Cardiac Life Support (ACLS) guidelines recommend against central venous lines in cases of cardiac arrest when peripheral venous access is difficult or impossible and instead recommends that providers use the intraosseous route for vascular access.⁴³

Professional organizations have issued statements acknowledging the importance of intraosseous access in patient care. The National Association of EMS Physicians (NAEMSP) has issued a position statement co-endorsed by the Air Medical Physicians Association (AMPA) on vascular access in pre-hospital settings. Although peripheral vascular access is preferred for most emergency situations, it is recognized that intraosseous vascular access provides rapid access to the vascular system for critically ill patients and is appropriate for initial vascular access in many cases.^{44, 45} The Infusion Nurses Society has also issued a position statement supporting intraosseous access if IV access cannot be obtained and the patient is at risk from lack of vascular access. This position paper also addresses intraosseous access as an appropriate procedure within the scope of practice for the qualified registered nurse. This position has been supported by the Emergency Nurses Association and the American Association of Critical-Care Nurses.^{46, 47, 48}

The European Resuscitation Council (ERC) and the International Liaison Committee on Resuscitation (ILCOR) concur with the AHA, NAEMSP, and AMPA in recommending early consideration of intraosseous access in critical situations.^{49, 50} These organizations recognize intraosseous access as safe and effective in resuscitation emergencies.

A CAMPAIGN TO SAVE LIVES

The IHI has sponsored several process improvement initiatives to reduce central line-related infections in hospitals. IHI targeted central line-related infections as one of six original initiatives for their successful 100,000 Lives Campaign to reduce preventable hospital deaths, and for the 5 Million Lives Campaign that concluded in December 2008.⁵¹ These initiatives culminated in development of a central line bundle – a set of five key practices to reduce central line infections.^{26, 40, 41}



THESE KEY GUIDELINES ARE:

- Proper hand hygiene for healthcare provider inserting the device
- Maximal sterile barriers during insertion
- Skin antisepsis with chlorhexidine prior to insertion
- Judicious selection of anatomic site for the catheter
- Daily inspection and prompt removal of the catheter when it is no longer necessary

These evidence-based practices have been identified by the CDC as effective in reducing central line infections.⁵ The IHI initiative relies on vigorous and continual monitoring of central line-associated infection rates. IHI's current initiative, the Improvement Map, also focuses on central line-related infections as one of 15 essential interventions for hospitals to improve patient care.⁵²

CURRENT INITIATIVES

Central line-related complications were once thought to be an unavoidable part of medical care. Hospitals now have the tools to dramatically reduce central line complication rates.^{53, 54, 55, 56, 57} A number of hospitals across the United States, and several in other countries, have reported success in reducing central line-associated infections by using evidence-based practices that include a central line checklist and/or a central line bundle.^{53, 54, 55, 56, 57, 60}

Much of the reported success in reducing central line-associated infections comes from studies in ICUs, where the environment and use of maximal sterile barriers can be carefully controlled.^{53, 54, 55, 56, 57} The surgical ICU at Johns Hopkins Hospital experienced a 94% reduction in central line-related infections by implementing full sterile barriers, among other precautions and educational training.⁵⁵ An important component of that project was that nurses were empowered to stop central line insertions if infection control practices were compromised. Other organizations have had similar success in reducing central line-associated infections. These studies are summarized in Table 6. However, despite the dramatic success demonstrated in the ICU, the non-ICU population is still at significant risk of central line-associated infection.⁵⁸ A 2009 AHRQ report (Agency for Healthcare Research and Quality) confirms the overall number of central line-associated bloodstream infections remains unchanged nationwide.⁵⁹

**TABLE 6:** Reductions in Central Line-Associated Infections

| SETTING | ORGANIZATION | PRE-INTERVENTION (INFECTIONS/1000 CATHETER DAYS) | POST-INTERVENTION (INFECTIONS/1000 CATHETER DAYS) | % CHANGE | REFERENCE |
|---------------------------------|--|--|---|-------------|---|
| Pediatric Cardiac ICU | Children's Hospital Boston | 7.8 | 2.3 | 69% | Costello Pediatrics 2008 ⁵⁴ |
| Surgical ICU | Johns Hopkins Hospital | 14.6 | 0.9 | 94% | Earsing Nursing Mgmt 2005 ⁵⁵ |
| ICU and surgical patients | Greater Cincinnati Health Council (4 hospitals) | 1.7 | 0.4 | 76% | Render JQPS 2006 ⁵⁶ |
| ICU | Allegheny General Hospital | 10.5 | 1.2 | 89% | Shannon JQPS 2006 ⁵⁷ |
| ICU | 32 hospitals in SW Pennsylvania | 4.31 | 1.36 | 68% | MMWR 2005 ⁶⁰ |

The reduction in central line infections at some hospitals is certainly a positive trend. However, a rigorous and comprehensive program must be implemented to reduce these infections. One study at a large teaching hospital found that evidence-based guidelines in the central line bundle were followed only 62% of the time in the intensive care setting.⁶¹ The use of maximal sterile barriers for both patients and staff can significantly reduce central line-associated infections.⁶² In emergency situations, particularly in the emergency department, it may not be possible to follow the evidence-based practices to reduce central line-associated infections due to critical or dangerous patient conditions. In these emergencies, rapid vascular access may take priority over sterile procedures. Additionally, although these guidelines can successfully reduce central line-associated infections, they do little to address mechanical or thrombotic complications, which may also have serious consequences.



ALTERNATIVE VASCULAR ACCESS: A NEW APPROACH

Intraosseous access is a viable alternative to central lines for administration of medications, fluids and blood products. The bone marrow space acts as a non-collapsible vein providing a direct conduit to the central circulation. When hemodynamic monitoring is not indicated and peripheral IV access is difficult, the intraosseous route provides rapid vascular access and avoids unnecessary central line placement. During emergencies the patient's condition may prevent strict adherence to central line insertion protocols. The intraosseous route is effective in emergency conditions as a bridge to long-term vascular access allowing for central lines to be placed later using maximal sterile technique.

Intraosseous vascular access is increasingly popular in emergency and critical care medicine, due to the introduction of several FDA-cleared devices to facilitate access to the intraosseous space. These devices include the FAST1® (Pyng Medical, Richmond BC, Canada), the Bone Injection Gun® (WaisMed USA, Houston, TX, USA) and the EZ-IO® (Vidacare Corporation, Shavano Park, TX, USA).

Several review articles address the physiological aspects of intraosseous infusion, indications for use in adults and children, appropriate anatomical sites, and current practice.^{63, 64, 65, 66, 67, 68} Typically the time from skin preparation to successful vascular access was between two and three minutes using the intraosseous route.^{67, 68, 69, 70, 71} Some devices allow vascular access to be attained in less than 10 seconds.^{72, 73} In contrast, central line cut down and insertion can take 15 minutes or more.⁶⁷ Medications administered intraosseously are pharmacokinetically equivalent in blood serum concentrations to those administered intravenously.^{74, 75, 76, 77}

Anatomical sites for intraosseous access vary by device. The proximal tibia is the preferred site for the Bone Injection Gun®. The FAST-1® is cleared for use only in the sternum. The EZ-IO® has been FDA-cleared for the proximal tibia, the distal tibia and the proximal humerus. Recent studies have validated the proximal humerus as a viable site for the EZ-IO®.^{67, 69, 78} Head-to-head comparisons of specific intraosseous devices also exist in the literature.^{79, 80, 81}

There are several contraindications to intraosseous placement. These include fracture; a recent orthopedic procedure or prosthetic limb; intraosseous placement in a limb within 24 hours; infection over the site and the inability to correctly identify landmarks.^{64, 66, 68}

The utility of intraosseous devices has been confirmed in studies of EMS services and hospitals in several countries.^{67, 68, 69, 70, 72, 81, 82, 83, 84, 85} All of these studies reported success rates for insertion and intraosseous infusion with the EZ-IO® ranging from 90-98%, except one, with an 87% success rate. In a study of EMS departments in Portland, the intraosseous needle was placed in the intraosseous space in less than 6 seconds in 98% of cases.⁷²



The intraosseous route is also ideal for rapid vascular access under hazardous conditions. Three studies found that emergency care providers in HAZMAT (hazardous materials) suits were able to establish vascular access via the intraosseous route under simulated conditions.^{85, 86, 87} In one study, the average time to vascular access was 17 seconds by the intraosseous route versus 63 seconds for peripheral venous lines.⁸⁶ A pre-clinical study by Borron and colleagues also confirmed that intraosseous access was significantly faster than traditional intravenous lines.⁸⁷

Intraosseous access with manual needles has been in use for pediatric patients for many years. Several recent studies and reviews conclude the new generation of intraosseous access devices to be instrumental in establishing rapid vascular access in these young patients as well as adults in emergency situations.^{66, 71, 88, 89}

INTRAOSSIOUS ACCESS COMPLICATIONS

In contrast to central venous lines, complications are extremely rare with the intraosseous vascular access route, particularly with new generation intraosseous devices. The largest study of an intraosseous device to date, a retrospective case series of 1,199 patients receiving emergency vascular access with the EZ-IO,[®] found the most prevalent complication to be extravasation in 0.8% of patients.⁷⁰ A prospective study of the EZ-IO[®] in 250 adults found no serious complications (osteomyelitis, fracture, infection, extravasation, compartment syndrome or needle bending/clogging).⁸⁴ A published study of the BIG[®] device also cited no complications.⁹⁶ In several published studies with the modern intraosseous devices, FAST-1,[®] EZ-IO[®] and BIG,[®] conducted in a variety of settings (e.g. field emergency medical services, hospitals, and military battlefields) results are similar, with none reporting a single case of infection or serious complication.^{67, 68, 69, 71, 72, 74, 80, 81, 82, 90, 91, 92, 93, 94, 95, 96}

Studies conducted before the introduction of modern intraosseous access devices demonstrate a similar complication profile, with slightly higher rates of complications. Osteomyelitis and soft tissue infections were the most frequent complications, occurring in 0.6% of patients.⁹⁷ These complications were attributed to poor sterile technique in the emergency setting and extended placement of the device (greater than 72 hours).⁹⁸ Although extremely rare, other observed complications included extravasation, pain, fracture, compartment syndrome, and infusion failure due to needle bending or clogging.^{99, 100, 101} Again, these studies were conducted prior to development of modern intraosseous devices, which have much better safety profiles.

Table 7 provides a side-by-side comparison of complication rates for central venous catheters and intraosseous needles.



A COMPARISON OF TWO MODES OF VASCULAR ACCESS

TABLE 7: Frequency and Seriousness of Complications

| CENTRAL VENOUS CATHETER | | | |
|-------------------------|---|---|--|
| SEVERITY | FREQUENT | OCCASIONAL | RARE |
| Serious | DVT (among critically ill, 30%) ¹⁸ | Infection (5-9%) ^{18, 56} Deep vein thrombosis (8.5-26.2%) ¹⁹ Pulmonary embolism (among critically ill 15%) ¹⁸ Arterial puncture (3.5%) ⁵⁶ | Death (due to infection 1%) ⁵⁶ Air embolism (0.5%) Hemorrhage/Pneumothorax (1-3%) ^{103, 104} |
| Less Serious | | Hematoma (4.5%) ¹⁹ | |
| Minor | | Malposition (9.6%) ¹⁰⁵ | |

| INTRAOSSEOUS VASCULAR CATHETER | | | |
|---|----------|------------|---|
| <i>Complication rates reported below are from individual studies and reflect the complication rate for that study only. The introduction of modern intraosseous devices has led to increased usage of the intraosseous route for vascular access. The complication rate for IO may change based on results from current or future research.</i> | | | |
| SEVERITY | FREQUENT | OCCASIONAL | RARE |
| Serious | | | Osteomyelitis (0.6%) ⁹⁷ |
| Less Serious | | | Extravasation (0.8%) ⁶⁹ Subcutaneous abscess (0.1%) ⁹⁷ |
| Minor | | | Leakage (0.4%) ⁶⁹ Removal problems (0.2%) ⁶⁹ |



SUMMARY

Central venous lines, although effective in establishing vascular access, are time-consuming to insert and are associated with high complication rates, with accompanying patient morbidity and mortality. Intraosseous vascular access is a safe, effective and easy-to-use alternative to central lines when vascular access is medically necessary or urgently needed. Intraosseous access can also be used as a bridge to treat and stabilize the patient prior to establishing long-term vascular access through a central line.

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