Managing Central Venous Access during a Healthcare Crisis

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ARTICLE HIGHLIGHTS

Type of Research: Multi-center cross sectional cohort study of experiences with central venous access line teams during the COVID-19 pandemic.

Key Findings: Participants from 60 hospitals in 13 countries contributed data. 75% of line teams included a vascular surgery attending physician. 2,657 central

venous lines were placed at 20 of the participating sites with 11 (0.41%) iatrogenic access complications associated with procedures performed by the line team.

Take home Message: Implementation of a dedicated central venous access line team during health care emergencies, with staffing by physicians with central venous access expertise, a dedicated line cart, specific anatomic sites for different venous access needs, and a method to track complications, can improve outcomes and reduce iatrogenic complications.

Table of Contents Summary

Implementation of dedicated central venous access line teams during health care emergencies, with staffing by physicians with central venous access expertise, a dedicated line cart, recommended sites for access, and a method to track complications, can improve access delivery and may reduce the risk of iatrogenic complications and mortality.

Abstract

Introduction: During the COVID-19 pandemic, central venous access line teams were implemented at many hospitals throughout the world to provide access for critically ill patients. The objective of this study was to describe the structure, practice patterns and outcomes of these vascular access teams during the COVID-19 pandemic.

Methods: We conducted a cross sectional, self-reported study of central venous access line teams in hospitals afflicted with the COVID-19 pandemic. In order to participate in the study, hospitals were required to meet one of the following criteria: a) development of a formal plan for a central venous access line team during the pandemic, b) implementation of a central venous access line team during the pandemic, c) placement of central venous access by a designated practice group during the pandemic as part of routine clinical practice, or d) management of an iatrogenic complication related to central venous access in a patient with COVID-19.

Results: Participants from 60 hospitals in 13 countries contributed data to the study. Central venous line teams were most commonly composed of vascular surgery and general surgery attending physicians and trainees. Twenty sites had 2,657 lines placed by their central venous access line team or designated practice group. During that time, there were 11 (0.4%) iatrogenic complications associated with central venous access procedures performed by the line team or group at those 20 sites. Triple lumen catheters, Cordis® catheters and non-tunneled hemodialysis catheters were the most common types of central venous lines placed by the teams. Eight (14%) sites reported experience placing central venous lines in prone, ventilated patients with COVID-19. A dedicated line cart was used by 35 (59%) of hospitals. Less than 50% (24, 41%) of the participating sites reported managing thrombosed central lines in COVID-patients. Twenty-three

of the sites managed 48 iatrogenic complications in patients with COVID-19 (including complications caused by providers outside of the line team or designated practice group).

Conclusions: Implementation of a dedicated central venous access line team during a pandemic or other healthcare crisis is a way by which physicians trained in central venous access can contribute their expertise to a stressed healthcare system. A line team composed of physicians with vascular skill sets provides relief to resource-constrained ICU, ward, and emergency medicine teams with a low rate of iatrogenic complications relative to historical reports. We recommend that a plan for central venous access line team implementation be in place for future healthcare crises.

Introduction:

The novel coronavirus, SARS-CoV-2, has caused 7,293,307 cases of Coronavirus Disease 2019 (COVID-19) worldwide (as of June 10, 2020) and 413,126 deaths. Of those cases, 1,990,112 have been in the United States with 112,441 associated deaths between February 6, 2020 and June 10, 2020[1]. Approximately 5-10% of patients with COVID-19 require admission to the intensive care unit and mechanical ventilation[2-3]. In these critically ill patients, the rates of septic shock and acute kidney injury are 20% and 15%, respectively[4-5]. As a result, these patients often require central venous access for the infusion of vasoactive agents and/or hemodialysis.

In the COVID-19 crisis, overburdened health care systems throughout the world have had to address the need to provide central venous access for the unprecedented dramatic influx of critically ill patients, particularly during the surge period of the pandemic. As a result, the procedure of placing central venous access, which is normally a routine occurrence in critical care units, has created unique challenges during the COVID-19 pandemic given the limited providers available to manage the extraordinary increase in critically ill patients. The limited resources may lead to central venous access procedures being performed by less experienced and/or overworked physicians, which results in an increased rate of serious complications[6]. Furthermore, central venous access procedures can result in physicians being occupied for a prolonged period by a single patient while the issues of other acutely ill patients are not being addressed. In the case of a COVID-19 positive patient, the central venous access procedure includes not only the time required to perform the procedure, but also the additional time required to don and doff the added personal protective equipment required.

During the COVID-19 pandemic, central venous access line teams have been developed at many hospitals throughout the world to handle the access needs of all patients in the hospital, freeing physicians with less experience in central venous access and those who are overburdened by acute and critical demands to focus on management of other patients requiring their attention[7-8]. The teams often consist of vascular surgeons, general surgeons, interventional radiologists, anesthesiologists, intensivists, and interventional cardiologists who have been trained and have extensive experience in central venous access, as well as experience identifying and managing the complications associated with central venous access procedures[9-10]. For example, to meet the increased demand for critical care providers at the University of Massachusetts, vascular surgeons formed a "Surgical Workforce Access Team (SWAT)" in order to best leverage the skillsets of vascular surgery division members and provide the best service to the hospital and to their colleagues[7]. At Mount Sinai Hospital in New York, physicians recognized a dramatic increase in the rate of central line complications and the resulting urgent vascular interventions. In response, the vascular surgeons created a line team[8].

While central line teams and protocols for line placement and management have been described in the past, those efforts have been focused on reducing central line-associated bloodstream infections rather than addressing a pressing need during a healthcare disaster[11-13]. Within the context of early isolated single-institution reports, we sought to provide a multi-institutional experience of line teams during the pandemic. The objective of this study was to describe the structure, practice patterns, and outcomes of these line teams on central venous access procedures and their related complications.

Methods:

We conducted a cross-sectional, self-reported study of structured central venous access line teams and the physician groups providing central venous access in hospitals afflicted by the COVID-19 pandemic. In order to participate in the study, hospitals were required to meet one of the following criteria: a) development of a formal plan for a central venous access line team during the pandemic, b) implementation of a central venous access line team during the pandemic, c) placement of central venous access by a designated practice group during the pandemic as part of routine clinical practice, or d) management of an iatrogenic complication related to central venous access in a patient with COVID-19

This study was a collaborative effort between the Vascular Low Frequency Disease Consortium (VLFDC) and the Vascular Surgery COVID-19 Collaborative (VASCC). The VLFDC is a multi-institutional collaboration, initiated 20 years ago, and designed to investigate uncommon vascular diseases[14]. The VASCC was established on March 2, 2020 to study the impact of the ongoing COVID-19 pandemic on vascular surgical care[15], using an international registry.

The Institutional Review Board of the University of California Los Angeles (UCLA) deemed this study protocol exempt as a quality improvement project.

Database development

The primary investigators (KW, TC, DJ, DR) initially developed the registry data elements by determining factors important to the structure and function of central venous access line teams' experience of line placement during the pandemic, as well as iatrogenic complications associated with line placement. The draft registry was reviewed by a group of physician investigators with central venous line placement expertise and revised in an iterative

fashion until no further modifications were recommended by the group. This established the final standardized dataset for collection that constitutes the basis of this study.

Data collection

The study was disseminated through the VLFDC and VASCC electronic mailing lists and social media. Study data were collected and managed using REDCap (Research Electronic Data Capture), a web-based data collection mechanism designed for research[16]. Data entry into the registry opened on April 22, 2020 and closed on May 4, 2020. Study participants were required to record responses to all items in the database. Participants were contacted via electronic mail by the UCLA vascular research center for clarification of any discrepancies in the submitted data and missing data.

Participants were required to enter their hospital characteristics, utilization of central venous access line teams during the pandemic, types of patients and locations in which the line team services were offered, team composition, team availability, criteria for activation and termination of their services, and anatomic sites used for access. Each institution was asked to provide details regarding any iatrogenic complications associated with central venous line placement, and if available, the total number of central venous access procedures performed during the time that the line team or designated practice group placing central lines was in place. Each institution was also given the opportunity to provide insight regarding successful management of central venous access during the pandemic.

Results

Demographics

Participants from 60 hospitals in 13 countries contributed data to the study (Appendix A). Fifty-eight of the hospitals had plans in place for a central venous access line team, had implemented the line team, or had a designated practice group placing central venous lines for the hospital outside of a formal line team structure. Two of the participating hospitals had not developed or implemented a line team or designated a group to place lines, but had managed an iatrogenic complication related to central venous access in a patient with COVID-19. Most of the hospitals that participated were urban, academic, university-affiliated hospitals with more than 400 beds (Table 1). Thirty-one of the hospitals had developed and implemented a central venous access line team specifically for the pandemic, while five hospitals had a plan for a line team but had not yet implemented it. Twenty-five of the participating hospitals had a physician group placing central venous lines as part of their routine clinical practice, without being designated as a "line team." Eight of the hospitals that implemented a line team had a central venous access line team in existence prior to the pandemic, with four making no changes once the pandemic started. Two changed the PPE protocols for their line teams with the onset of the pandemic. One made services available on the weekends and ensured that attending physicians were physically present in the hospital at all times. One had a pre-existing medical proceduralist team which remained in place with the addition of a surgical team to supplement or take over their responsibilities when the medical specialists get called to take care of patients.

Central venous access line teams were most commonly composed of vascular and general surgery attending physicians and trainees, with some hospitals including attending physicians and trainees of other specialties such as interventional radiology and anesthesiology (Figure 1). Nearly all of the line teams were developed served or intended to serve patients who had tested positive for the SARS-CoV-2 virus (COVID-19+) in the intensive care unit setting

(ICU) (42, 96%) as well as patients under investigation for SARS-CoV-2 infection (COVID-19PUI) in the ICU (40, 90%). Fewer line teams included patients who had tested negative for the SARS-CoV-2 virus (COVID-19-) in the ICU (28, 66%). Most line teams also provided service for COVID-19+ and COVID-19PUI patients on the floor setting (28, 64%). Some line teams provided services for COVID-19+ (25, 57%) and COVID-19PUI (22, 50%) patients in the emergency department.

The plan to utilize the services of a central venous access line team during the pandemic was most commonly initiated by the vascular surgery division/department (15, 34%) or critical care team (11, 25%). The burden of COVID-19+ patients exceeding a critical threshold at the institution, where providers with training were present but overwhelmed, was cited as one of the reasons for implementing the line team by 22 (50%) of hospitals. The importance of minimizing line placement complications was cited as one of the reasons for implementation by 23 (52%) of hospitals. The majority of line teams made their services available daily at all hours (28, 64%), while at some hospitals (5, 12%), the timing of line team service availability varied by the phase of the pandemic and the stress on the resources in their hospital. These hospitals required exceeding a critical volume threshold for the central venous access line team to become activated. The criteria for terminating the line team services included a combination of: 1) reduction of hospitalized COVID patients to below a critical threshold (64%), 2) increased availability of other providers with line placement skills (25%), and 3) line team members returning to regular duties (41%).

Central venous access line team characteristics

In the 58 hospitals placing lines, six sites (10%), had no trainees involved in central venous line placement procedures. At eleven hospitals (19%), the attending physician was in the room during every line placement procedure. Of the 41 remaining hospitals, 30 had trainees that were at least at post-graduate year three level performing the central venous access procedures, with attending physicians immediately available.

Triple lumen catheters (TLCs), Cordis® catheters, non-tunneled hemodialysis catheters (NTHDCs) and tunneled hemodialysis catheters (THDCs) were the most common types of central venous lines placed (Figure 2). Six of the hospitals also performed peripherally inserted central catheters (PICC); however, they reported that this practice was in place prior to the pandemic and remained unchanged.

Among the 44 hospitals with line teams in place or planned, additional line team services provided, beyond central venous line placement during the COVID-19 pandemic, included: arterial line placement (82.8%), orogastric/nasogastric tube placement (18%), tube thoracostomy (16%), Foley catheter placement (10%), intubation (7%), tracheostomy (5%), gastric tube placement (2%), and rectal tube placement (2%). For the 31 hospitals with line teams in place, the reported numbers of central venous line placements performed over the seven days preceding participation in this study varied from <10 to >40, with the most common category being >40 (Table 1).

Anatomic considerations

The internal jugular veins were the preferred sites for TLC and hemodialysis catheter (HDC) placement prior to the COVID-19 pandemic (Table 2); these continued to be the preferred sites during the pandemic for COVID-19+, COVID-19PUI and COVID-19- patients.

However, during the pandemic, the participating sites used the internal jugular and subclavian veins less frequently than prior to the pandemic, while the great saphenous (GSV) and popliteal veins (PV) were used more frequently. For supine COVID-19+ patients, the first choice for TLC placement was the right internal jugular vein in 31 (52.5%) hospitals and the left internal jugular vein in 22 (37.3%). The first-choice location for HDC placement was the right internal jugular vein in 46 (82.1%) of the hospitals. Similar patterns were found for COVID-19PUI (Table 2).

Most participating sites considered similar anatomic locations for COVID-19+ and COVID-19- patients; however, 18 (30.5%) sites reported that their preferences for venous access in COVID-19+ patients were different from COVID-19- patients, with the most common reason being the ease of accessibility and the likelihood of kinking the catheters if the patient required prone positioning. Other considerations included the risk of pneumothorax and the proximity to the patient's airway, potentially increasing the risk of infection to the providers performing the procedure. In addition, 16 (27%) sites considered renal failure or impending renal failure requiring dialysis as a factor in choosing anatomic location for TLCs or HDCs. Most reported preserving the right internal jugular vein for HDCs and avoiding the femoral veins for HDCs for potential prone positioning required for COVID-19 treatment.

Eight (14%) sites reported experience with placing central venous lines in prone, ventilated COVID-19+ patients, with no associated complications. Six of the sites always delayed line placement until the patient returned to the supine position, or they requested that the patient be returned to the supine position for the procedure. One site placed the lines with the patient remaining in the prone position. Two sites placed the line with the patient remaining in the prone position if they could safely access the vein laterally. In this population of patients who required prone positioning, TLCs continued to be placed in either the right or the left internal

jugular veins, the femoral vein, or the great saphenous vein. HDCs were placed exclusively in the right internal jugular vein. Three lines were placed while the patient remained in the prone position: 1) a TLC placed in the popliteal vein, 2) a NTHDC placed in the right internal jugular vein, and 3) a TLC placed in the right internal jugular vein. Standard line placement techniques were used with ultrasound guidance and percutaneous Seldinger technique.

All 58 sites placing central venous lines during the COVID-19 pandemic used ultrasound guidance during line placement and nearly all participants (52, 90%) reported obtaining a chest X-ray (CXR) to confirm line placement for internal jugular or subclavian lines in COVID-19+ patients. Those who did not obtain a CXR acknowledged that this deviated from their normal practice. Their rationale for not utilizing a CXR was to limit exposure of hospital staff and radiology technologists, while conserving personal protective equipment (PPE).

Supplies and PPE utilization

A dedicated line cart was used at 35 (59%) hospitals. The most common items stored in these line carts were: kits for TLCs, HDCs, Cordis® catheters (100%), sterile gloves (97%), sterile gowns (97%), sterile preparation sticks (94%), sterile gauze (94%), ultrasound probe covers (94%), selection of syringes (91%), sterile saline flushes (91%), sutures (91%), masks (91%), and bouffant hats (85%) (Appendix B).

PPE utilization patterns by line teams in COVID-19+ patients and COVID-19PUI were similar (Table 3). A small but significant number of line teams continued to use N95 masks with or without surgical masks, even in COVID-19- patients (Table 3). When asked if hospitals experienced an increased incidence of needle sticks to providers associated with central line

placement during the COVID-19 pandemic, 28 (47%) responded “no” and 31 (52%) “did not know”.

Prevention and management of thrombosed central lines

Less than 50% (24, 41%) of the participating sites in this study reported managing thrombosed central lines in COVID-19+ patients: 19 (33%) sites reported managing at least one thrombosed TLC, 21 (36%) HDC, and 2 (3%) Cordis® catheters. Over half of the sites (32, 54%) believed that central lines were more likely to thrombose in COVID-19+ patients, compared to COVID-19- patients, due to hypercoagulability. Most also believed that HDCs were more likely to thrombose in COVID-19+ patients than any other type of central venous lines.

Only 13 (22%) participating sites recommended varying types of routine anticoagulation in COVID-19+ patients to maintain central line patency, including: prophylactic dosing of unfractionated heparin (4 sites), therapeutic dosing of unfractionated heparin (1 site), prophylactic dosing of low molecular weight heparin (5 sites), and therapeutic dosing of low molecular heparin (2 sites). The two remaining hospitals anticoagulated all COVID-19+ patients, regardless of whether the patient had a central venous access line in place. The majority of the participants who recommended anticoagulation were concerned about a high rate of thrombosis in COVID-19+ patients and recommended anticoagulation to minimize resource utilization.

Only 7 (12%) participating sites were routinely changing central lines. Of those 7 sites, 5 reported that routine changing of lines was part of their regular practice, regardless of the pandemic. One site changed the line every three days, one every four days, four every seven days and one every eight days.

Complications and deaths

Twenty participating sites reported 2,657 lines *placed by their designated group or line team in COVID-19+, COVIDPUI and/or COVID-19- patients*; there were 11 (0.4%) iatrogenic complications associated with central venous access line placement procedures performed by the designated group or line team at those sites. These consisted of two inadvertent placements of a catheter into an artery, seven instances of hematoma or active bleeding at catheter sites, one instance of pneumothorax and one air embolism. The air embolism was in a COVID-19+ patient who was not intubated and the patient expired shortly thereafter. This was the only death directly related to an iatrogenic venous access complication.

A total of 48 iatrogenic complications of central venous line placement *in the COVID-19+ population* were managed by 23 (38%) participating sites, including complications associated with procedures performed by providers *outside of their line team or designated group* (Table 4). The most common type of complication was inadvertent placement of a catheter into an artery. In 20 of the complications, the participating site believed something could have been done differently during the initial access attempt to prevent the complication. In almost all of these cases, the participating site believed that a combination of a more experienced operator, meticulous use of ultrasound, and maintaining wire control at all times could have prevented the complication.

With respect to the COVID-19+ population, in one case of inadvertent puncture of the artery, the wire was left in the femoral artery and the patient was anticoagulated, since the patient was deemed too unstable for intervention. In three of the cases of inadvertent placement of a catheter into an artery, the patient was deemed too unstable from COVID-19 to undergo an

intervention. In all but three of the complications in the COVID-19+ population, the participating sites indicated that they would have managed the iatrogenic complication in a COVID-19- patient in a similar manner to what was done in the COVID-19+ patient. For three complications, the sites stated they may have considered more aggressive surgical or interventional management if the patient had not been COVID-19+.

Discussion:

We describe the formation, implementation and results of dedicated central venous access line teams led by physicians with central venous access expertise during the COVID-19 pandemic. These dedicated line teams served as an invaluable resource in stressed health care systems. This is aptly demonstrated by the 2,657 lines placed by 20 of the line teams. Each of these lines represents an instance where the line team enabled the ICU team to focus on the care of an unprecedented high volume of critically ill patients, rather than spend time preparing for the procedure, donning and doffing PPE and performing the procedure. These line teams represent "bringing together elements to ensure an effective response", which is a key point that is repeatedly emphasized in disaster management[17].

The rapid spread of the pandemic exposed a lack of disaster preparedness in hospitals worldwide[18]. Most healthcare disasters occur without notice[19]. In order to optimize outcomes during a disaster, plans for managing a disaster need to be in place prior[17,19]. The lessons learned from this initial line service experience can be readily applied to future healthcare crises and future surges of the COVID-19 pandemic. In fact, at the time of this writing (June 10, 2020), stay-at-home orders are being lifted across the US. Since the stay-at-home order was lifted in

Arizona on May 16, cases have increased by 108% in that state with an associated increase in hospitalizations and strain on the healthcare system[20].

Vascular surgeons are uniquely trained to lead dedicated central venous access line teams, since a vascular practice usually encompasses routine percutaneous arterial and venous access, invariably using ultrasound guidance. The technical skills necessary to perform a high volume of these procedures, with a low complication rate, are critical for these teams to be of value. Based on the experiences of the participants in this study, we have identified a set of best practices for central venous line placement during times when hospital systems are stressed by disasters such as the COVID-19 pandemic.

Standard Practices

Line Team Implementation: Each institution should determine an appropriate schedule for line team activation, based on available resources and individual institutional needs. Ideally, the team should be available throughout the day, and any limitations should be communicated to the intensive care units and emergency rooms. The ramp-up and ramp-down of the line team should be individualized to the needs of the institution and the central venous access service line. A number of participants in this study highlighted the importance of understanding variations in individual institutional resource allocation, with this being a key to providing service at the optimal time and place.

Line Cart: An adequately stocked line cart increases the efficiency of line placement procedures. This cart should have all the supplies and PPE necessary to safely perform central venous line placements and remain outside the room to reduce cross contamination. Having an appropriately stocked cart, as pointed out by a number of participants, reduces donning and

doffing of PPE, minimizes potential provider exposure, and allows for a more streamlined and efficient placement of venous access. Appendix C demonstrates equipment we recommend on a line cart, including PPE.

PPE: It is paramount that proceduralists be provided with appropriate PPE. We found that the majority of our respondents were following best practices for PPE utilization – wearing an N95 mask, covered by a surgical mask, protective eye wear, bouffant/surgical cap, and a gown and gloves for COVID-19+ patients. A number of sites recommended that there should be no more than two providers in the room, with a "runner" outside the room, who can retrieve additional supplies as needed, in order to preserve PPE and minimize exposure.

Location of Central Lines: The preferred location of central venous access lines was relatively consistent across respondents. Given the high incidence of acute renal failure and need for acute hemodialysis in the COVID-19+ population, most centers preferably placed central lines in the left internal jugular vein, reserving the right internal jugular vein for non-tunneled hemodialysis lines. Given the high rate of COVID-19+ ICU patients requiring prone positioning, femoral lines were avoided; several centers reported placing popliteal vein lines in these patients. Subclavian lines were also discouraged, given the known increased incidence of pneumothorax over internal jugular lines. Several centers used 55cm hemodialysis lines intended for tunneled placement, in a non-tunneled fashion when femoral dialysis access was needed. The cuff remained outside the patient, with the intent that the extra catheter length and stiffer catheter material would help to reduce kinking and displacement when the patient required prone positioning.

Ultrasound guidance: All centers utilized ultrasound guidance when performing central venous access. Notably, participating sites believed that over half of the iatrogenic complications they managed could have been prevented with meticulous use of ultrasound guidance. Ultrasound guidance has become the standard of care in placement of central lines and should continue to be used in disaster situations such as the COVID-19 pandemic, despite the additional time required to thoroughly clean the machine between uses[21]. Participants recommended confirming wire position in the long axis ultrasound view and using a sterile cover over the entire ultrasound probe and machine during the procedure to reduce the risk of cross-contamination. Wireless ultrasound transducers may be particularly useful in this clinical scenario[(10)].

Post Placement Confirmation: In critically ill patients, reducing complications is paramount, and early identification of complications is a key to patient survival. Thus, obtaining a post-procedure chest X-ray to confirm the tip location and that no pneumothorax has occurred continues to be an important step used by the majority of hospitals, even in a limited resource situation. Careful examination of the images by the treating physician, to rule out pneumothorax, is of particular importance in intubated patients, especially with higher pressure ventilator settings.

Needlestick Prevention: We were reassured to see that there was a low incidence of needlestick injuries. In stressful situations, it is important to continue to practice safely, particularly with sharps and sharps disposal. Stressful and unfamiliar working conditions, lack of adequate protective medical/technical equipment and poor work routines are known to contribute to needlestick injuries[22]. Using an experienced, well-prepared team allows for the repetition and expertise needed to reduce needle stick injuries. During this particular pandemic, patients that are COVID-19+ or COVID-19PUI must both be handled with the same care, caution, and PPE.

Management of Hypercoagulability and Line Thrombosis: Hypercoagulability in the COVID-19+ population is well established[23-25]. We found variability among hospitals in reporting their experience with thrombosed central lines; consequently, prevention strategies also differed. The majority of thrombosed lines were NTHDC, and the thrombosis presumably occurred during continuous veno-venous hemofiltration, a known complication of a low flow hemodialysis session[26]. However, we were surprised to find the large number of TLCs that also thrombosed. Some participants recommended running continuous infusions of low-dose heparinized saline through any lines that are not being used for other infusions.

Complications: Complications secondary to central venous line placement are always expected; however, the overall complication rate of 0.4% when central venous lines are placed by dedicated line teams is significantly lower than the rate of up to 15% that has been previously published[27-28]. The incidence of arterial cannulation during central venous access has been reported to be in the range of 4.2%-9.3% of all line placements[29]. In a study of 539 central venous catheter placements under ultrasound and fluoroscopy guidance, 486 of the lines were primarily placed by a surgical trainee[30]. The associated complication rate was 8.4%, 93% of which were arterial punctures. This suggests a dedicated line team may not only increase efficiency of provider utilization in a pandemic but may also reduce complications in a fragile at-risk population.

Limitations

As with all studies using retrospective, self-reported data, there is a possibility of reporting error or inaccuracy. To minimize this risk we standardized the data points with specific definitions and carefully reviewed the submitted data to identify any discrepancies. All

discrepancies were clarified individually with the participating investigator. Our study would be strengthened by a matched contemporaneous comparison group of hospitals that did not implement a central venous access line team or designate a group to place lines. Another valuable comparison would be the rate of complications at participating hospitals before the pandemic. However, these types of studies require a complex study design with recruitment of matched hospitals and abstraction of data that was not readily available during the pandemic. This was not feasible at the time of the study, but could be performed in the future to quantify the impact of line teams on the incidence of iatrogenic central venous access complications. Lacking this, we relied on historical data in the literature for iatrogenic complication rates of central venous line procedures and anatomical preferences for central venous line placement.

This data was collected at the height of the pandemic for many participating institutions. As such, we sought to describe practice patterns that could possibly be useful to other institutions in preparing for future waves of the pandemic or other health care crises, using data that was easily accessible to participating institutions during the potentially chaotic time. This study serves as a hypothesis-generating study that brings up several granular issues relevant to the effectiveness of line teams, requiring more laborious data extraction that should be investigated in the future. A study examining the cost effectiveness of maintaining a line cart and dedicating personnel to line teams, balanced against the potential decrease in procedural complications and increased efficiency, would provide insight into the financial burden of implementing this intervention. Comparing the degree of change in volume of central line placements before the pandemic to during the pandemic, when the line teams were in place, would quantify the magnitude of the line placement challenge.

The unit of analysis in this study was the hospital. Patient-specific data were collected only in the case of complications and line placement in prone patients. Future studies utilizing patient-specific data addressing issues such as whether the rates of line sepsis were influenced by the pandemic would provide further insight into the impact of the pandemic on management of central venous access.

As physicians learn more about managing patients with COVID-19, practice patterns may change with regard to line team structure and function, preferred anatomic locations and other technical issues. A follow-up study in the future regarding “lessons learned” from central venous access during the pandemic and the associated changes in practice patterns in response would be valuable.

Conclusion:

The implementation of a dedicated central venous access line team is a way in which physicians trained in percutaneous central venous access can make a contribution to a stressed healthcare system during a pandemic or other healthcare crisis. A line team composed of physicians with vascular skill sets provides relief to resource-constrained ICU, ward, and emergency medicine teams with a low rate of iatrogenic complications relative to historical reports. We recommend that a plan for central venous access line team implementation be in place for future healthcare emergencies; including staffing, a dedicated line cart, recommendations on the optimal anatomic site and technique, as well as a method to track complications.

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Table 1. Hospital characteristics and central venous line placement volume

	Hospitals with line team in place or planned n=44 (%)	**Groups placing lines at their hospital outside of line team** n=14 (%)
Hospital characteristics		
Urban	44 (100)	14 (100)
Academic university	34 (77)	11 (79)
affiliated	4 (9)	2 (14)
Non-university affiliated	3 (7)	1 (7)
teaching	4 (9)	2 (14)
Community/private	1 (7)	5 (11)
Public		
Veterans affairs		
Hospital size by baseline beds		
100-199	5 (11)	1 (7)
200-299	3 (7)	1 (7)
300-399	6 (14)	1 (7)
>400	30 (68)	11 (79)
	Hospitals with line teams in place n=31 (%)	
Line placements in previous 7 days*		
0-10	7 (23)	
10-20	9 (29)	NA
20-30	2 (7)	
30-40	2 (7)	
>40	11 (36)	

*Line placements in the 7 days preceding data entry into the study

Table 2. Anatomic preferences for central venous catheter placements by COVID-19 status

	R IJ n (%)	**L IJ** n (%)	**R SC** n (%)	**L SC** n (%)	**Fem** n (%)	**GSV** n (%)	**Pop** n (%)
All anatomic locations considered viable							
Prior to Pandemic	59 (97)	58 (95)	41 (67)	39 (64)	52 (85)	2 (3)	0 (0)
COVID-19+	52 (85)	50 (82)	27 (44)	26 (43)	48 (79)	4 (7)	2 (3)
COVID-19PUI	55 (90)	51 (84)	27 (44)	27 (44)	49 (80)	4 (7)	1 (2)
COVID-19-	59 (97)	58 (95)	34 (56)	32 (53)	49 (80)	2 (3)	0 (0)
1st choice for supine patient							
COVID-19+							
TLC	31 (53)	22 (37)	2 (3)	0 (0)	4 (7)	0 (0)	0 (0)
HDC	46 (82)	0 (0)	2 (3)	0 (0)	8 (14)	0 (0)	0 (0)
COVID-19PUI							
TLC	30 (51)	23 (39)	2 (3)	0 (0)	4 (7)	0 (0)	0 (0)
HDC	45 (80)	0 (0)	2 (3)	0 (0)	9 (16)	0 (0)	0 (0)

R IJ: right internal jugular vein; L IJ: left internal jugular vein; R SC: right subclavian vein; L SC: left subclavian vein; Fem: femoral vein; GSV: greater saphenous vein; Pop: popliteal vein; COVID-19+: patient who has tested positive for SARS-CoV-2 virus; COVID-19PUI: patient under investigation for SARS-CoV-2 infection; COVID-19-: patient who has not tested positive for SARS-CoV-2 virus; TLC: triple lumen catheter; HDC: hemodialysis catheter

Table 3. Personal protective equipment used during placement of central venous lines populations by COVID-19 status

	COVID-19+ (%)	**COVID-19PUI (%)**	**COVID-19- (%)**
Surgical mask without N95	1 (2)	2 (3)	41 (67)
N95 without surgical mask	15 (25)	13 (21)	6 (10)
N95 with surgical mask over	45 (74)	46 (75)	12 (20)
Powered air-purifying respirator	10 (16)	8 (13)	2 (3)
Face shield	54 (89)	55 (90)	36 (59)
Gown	55 (90)	54 (89)	55 (90)
Bunny suit with hood	5 (8)	4 (7)	0 (0)
Bunny suit without hood	3 (5)	3 (5)	0 (0)
Bouffant/surgical cap	52 (85)	52 (85)	48 (79)
Goggles	2 (3)	1 (2)	0 (0)

COVID-19+: patient who has tested positive for SARS-CoV-2 virus; COVID-19PUI: patient under investigation for SARS-CoV-2 infection; COVID-19-: patient who has not tested positive for SARS-CoV-2 virus

Table 4. Iatrogenic complications of central venous line placement in COVID-19+ patients managed by participating sites.

			Anatomic Location					
Complication	**Total Number of cases**	**Cases related to line team procedure**	**IJ / Carotid**	**SC**	**Fem**	**Other**	**Initial Management Strategy**	**Initial Management Success**
Inadvertent arterial puncture with wire in place prior to catheter placement	3	0	2	0	1		Pull line and hold pressure (1) Open surgical repair (1) Other (1)	Yes Yes *
Inadvertent arterial puncture with dilator in place prior to catheter placement	2	0	1	0	0	Descending aorta	Pull line and hold pressure (1), Endovascular mgmt w stent (1)	Yes Yes
Inadvertent arterial placement with catheter still remaining in artery	16	1	5	6	4	Brachio-cephalic artery	Pull line and hold pressure (5), Endovascular mgmt w balloon (2), Closure device (1), Endovascular mgmt w stent graft (1), Open surgical repair (3), Used as arterial line then pulled (1) Other (3)*	Yes Yes Yes Yes Yes Yes *
Inadvertent arterial puncture with no catheter remaining in artery but active extravasation present	2	0	0	1	1		Pull line and hold pressure (2)	Yes
Catheter or wire fracture/embolization	3	0	0	0	1	aorta right atrium	Open surgical retrieval (1) Anticoagulation (2)	Yes
Hematoma or active bleeding at catheter site with catheter in place and catheter in	10	6	8	1	1		Pull line and hold pressure (10)	Yes

correct position								
Pneumothorax	11	1	4	5	0	2 unknown	Tube thoracostomy (11)	Yes
Air embolism	1	1	1	0	0		None attempted	No

*see text; IJ: internal jugular, SC: subclavian, fem: femoral

Figure 1.

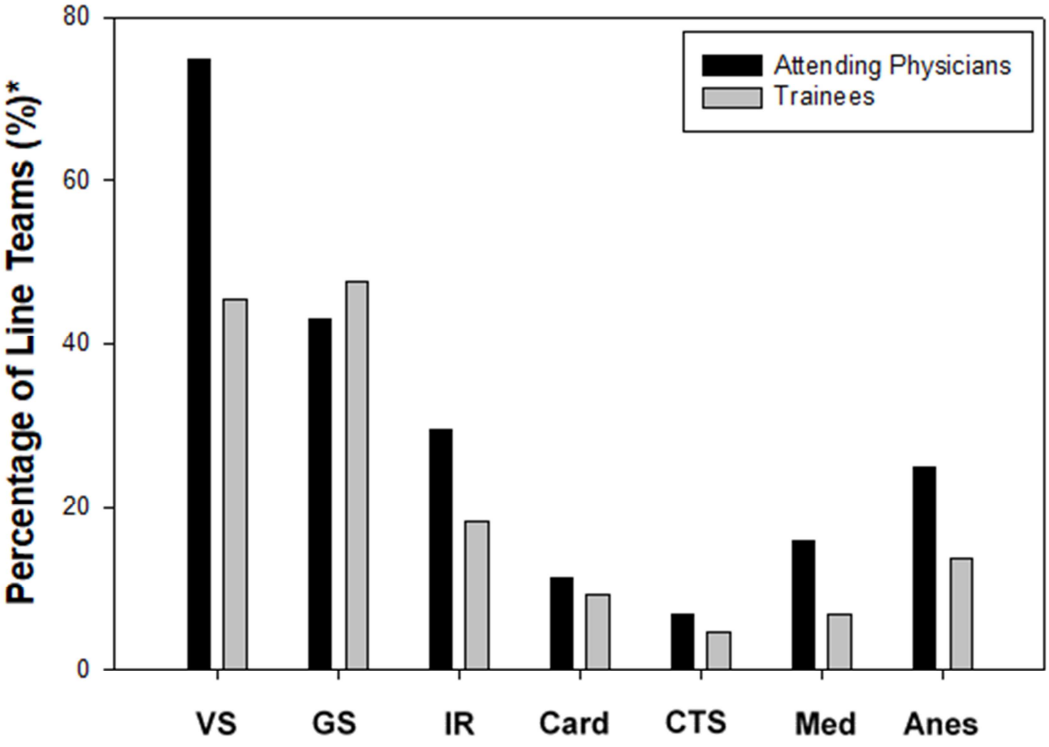
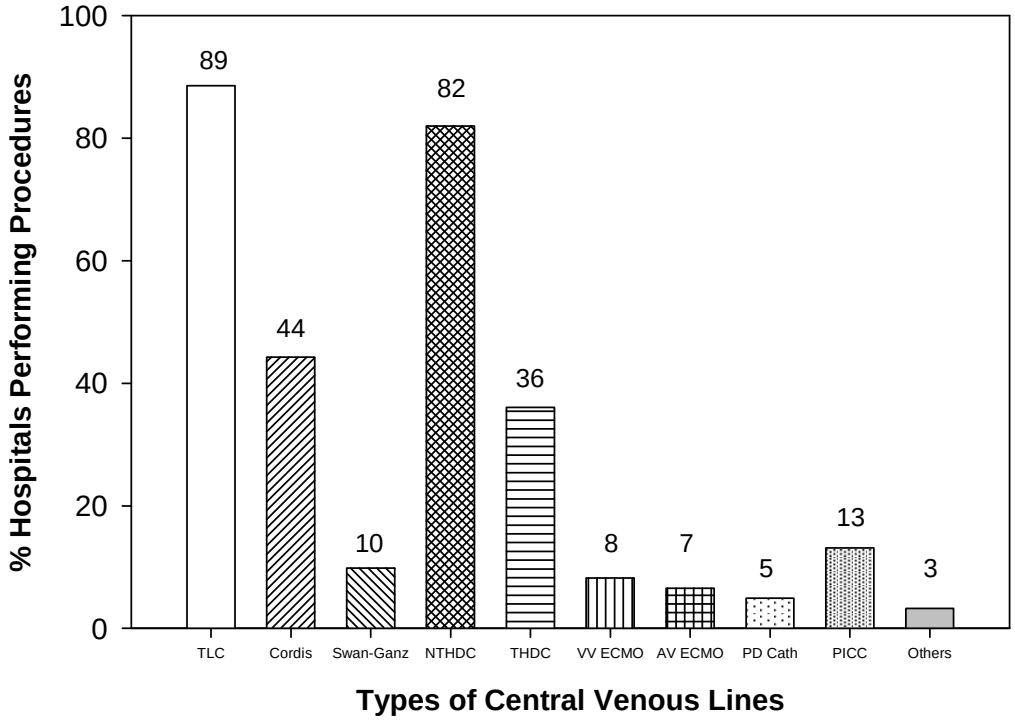

Percentage of Line Teams (%)*
80
60
40
20
0
Attending Physicians
Trainees
VS
GS
IR
Card
CTS
Med
Anes

Figure 2. Types of central venous lines placed by line teams (n=44).



TLC: triple lumen catheter; NTHDC: non-tunneled hemodialysis catheter; THDC: tunneled hemodialysis catheter; VV ECMO: veno-venous extracorporeal membrane oxygenation; AV ECMO: arterio-venous extracorporeal membrane oxygenation; PD: peritoneal dialysis; PICC: peripherally inserted central catheter; Others include: Infusaports, Hickman catheters and small bore sheaths for potential ECMO candidates

Figure 1. Central Venous Access Line Team Composition. VS: Vascular Surgery; GS: General Surgery: IR: Interventional Radiology; Card: Cardiology; CTS: Cardiothoracic Surgery; Med: Medicine; Anes: Anesthesia.

*Percentage of Line Teams that Include Attending Physicians and Trainees of Each Specialty

Figure 2. Types of central venous lines placed by line teams (n=44). TLC: triple lumen catheter; NTHDC: non-tunneled hemodialysis catheter; THDC: tunneled hemodialysis catheter; VV ECMO: veno-venous extracorporeal membrane oxygenation; AV ECMO: arterio-venous extracorporeal membrane oxygenation; PD: peritoneal dialysis; PICC: peripherally inserted central catheter; Others include: Infusaports, Hickman catheters and small bore sheaths for potential ECMO candidates

Table 1. Hospital characteristics and central venous line placement volume. *Line placements in the 7 days preceding data entry into the study

Table 2. Anatomic preferences for central venous catheter placements by COVID-19 status. R IJ: right internal jugular vein; L IJ: left internal jugular vein; R SC: right subclavian vein; L SC: left subclavian vein; Fem: femoral vein; GSV: greater saphenous vein; Pop: popliteal vein; COVID-19+: patient who has tested positive for SARS-CoV-2 virus; COVID-19PUI: patient under investigation for SARS-CoV-2 infection; COVID-19-: patient who has not tested positive for SARS-CoV-2 virus; TLC: triple lumen catheter; HDC: hemodialysis catheter

Table 3. Personal protective equipment used during placement of central venous lines populations by COVID-19 status. COVID-19+: patient who has tested positive for SARS-CoV-2 virus; COVID-19PUI: patient under investigation for SARS-CoV-2 infection; COVID-19-: patient who has not tested positive for SARS-CoV-2 virus

Table 4. Iatrogenic complications of central venous line placement in COVID-19+ patients managed by participating sites. *see text; IJ: internal jugular, SC: subclavian, fem: femoral

Appendix A. Hospitals represented in this study.

Appendix B: Items placed on dedicated line carts used by line teams.

Appendix C: Recommended items on a dedicated line cart

Appendix A. Hospitals represented in this study.

Country	State	Hospital
Canada		Vancouver General Hospital
France		Ambroise Paré University Hospital, AP-HP
Germany		University Medical Center Hamburg-Eppendorf
Greece		General Hospital of Athens KAT
India		Medanta Hospital
		Postgraduate Institute of Medical Education and Research
Italy		Policlinico Gaetano Martino
Korea (South)		Kyung Hee University Hospital at Gangdong
Mexico		Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán
New Zealand		Waikato Hospital
Singapore		National University Hospital
Sri Lanka		National Institute of Nephrology Dialysis and Transplantation
Switzerland		University Hospital Zurich
	AZ	Banner University Medical Center-Tucson
	AZ	Mayo Clinic Hospital
	CA	Community Regional Medical Center
	CA	Olive View- UCLA Medical Center
	CA	Palo Alto Veterans Affairs Medical Center
	CA	Ronald Reagan UCLA Medical Center
	CA	Veterans Affairs Greater Los Angeles
	CO	Rocky Mountain Regional Veterans Affairs Medical Center
	CO	Rose Medical Center
	CO	University of Colorado Anschutz Medical Campus
	IA	University of Iowa Hospitals and Clinics
	IL	Loyola University Medical Center
	IL	NorthShore University Health System
	IL	Northwestern Memorial Hospital
	IN	Eskenazi Health
	IN	Indiana University Health Methodist Hospital
	IN	Indiana University Health North Hospital
	IN	Indiana University Health West Hospital
	LA	Our Lady of the Lake
	LA	West Jefferson Medical Center
	MA	Boston Medical Center
	MA	Massachusetts General Hospital
	MA	University of Massachusetts Medical Center
	MD	The Johns Hopkins Hospital
	MI	Henry Ford Hospital
	MI	McLaren Bay Region
	MI	McLaren Flint

	MO	St. Louis University Hospital
	NJ	Overlook Medical Center
	NJ	Rutgers Robert Wood Johnson University Hospital
	NJ	University Hospital
	NY	Jacobi Medical Center
	NY	Montefiore Medical Center
	NY	Mount Sinai Brooklyn
	NY	The Mount Sinai Hospital
	NY	Mount Sinai Queens
	NY	New York-Presbyterian Columbia University Medical Center
	NY	New York- Presbyterian Queens
	NY	North Shore University Hospital, Northwell Health
	NY	Weill Cornell Medicine
	TX	Audie L Murphy Veterans Affairs Hospital
	TX	Dallas Veterans Affairs Medical Center
	TX	Memorial Hermann-Texas Medical Center
	TX	University of Texas Health Science Center at San Antonio University Hospital
	UT	University of Utah Hospital
	VA	Virginia Commonwealth University Medical Center
	WA	University of Washington Medical Center

Appendix B: Items placed on dedicated line carts used by line teams.

Item	(%)
Central line kits	100
Sterile gloves	97.1
Sterile gowns	97.1
Sterile preparation sticks	94.3
Sterile gauze	94.3
Ultrasound probe cover	94.3
Selection of syringes	91.4
Sterile saline flush	91.4
Sutures	91.4
Masks	91.4
Bouffant hats	85.7
Selection of hypodermic needles	80.0
Surgical towels	80.0
Tape	77.1
Selection of sterile drapes	77.1
Face shields	77.1
Lidocaine	74.3
Micropuncture sets	74.3
3-way stopcock	71.4
Antimicrobial dressing	71.4

Appendix C: Recommended items on a dedicated line cart

PPE:

Gloves
Gowns
Bouffant head covering
Masks: surgical, N95
Face Shields
Boot covers

Non-sterile items:

Tape
Coban
Arm boards

Sterile items:

Central Line Kits
Non-tunneled hemodialysis access kits
Arterial line kits (Arrow, micropuncture)
12” extension tubing
Surgical towels
Drapes: for arterial lines, central lines
Sterile gloves
Sterile gowns
Sterile preparation sticks
Sterile gauze
Selection of syringes
Selection of hypodermic needles
Suture
Ultrasound probe cover
Lidocaine
3-way stopcock
Antimicrobial dressing