Standardizing Preoperative Evaluation for Pediatric Central Venous Access

A Care Algorithm to Improve Safety

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ABSTRACT

Central vascular access device (CVAD) placement is a common procedure in children. When selecting a CVAD, available evidence and specified indications should be used to choose the device that best supports the patient's treatment and carries the lowest risks. A multidisciplinary team developed a care algorithm to standardize preoperative screening before pediatric CVAD placement, with 3 major parts: CVAD selection, patient risk stratification, and preoperative evaluation. Using a stepwise approach of provider education and incorporation into the electronic health record, the team achieved 82% stratification among inpatients. The team's algorithm integrates the existing literature and recommendations for safe and effective CVAD placement.

Key words: care algorithm, CVAD complications, pediatric central venous access, quality improvement

A central vascular access device (CVAD), also called a central venous catheter or central line, is a common device placed for medication delivery, hemodynamic monitoring, blood sampling, and other medical treatments.[1] Overall, CVAD insertion has been proven to be a safe procedure in both adults and children; however, like any surgical procedure it carries a risk of serious complications that may be higher among children. Such complications are typically divided into either early or late complications, which have different methods of treatment and prevention.[2] These complications are not only hazardous to the patient but can also be difficult and expensive to treat.[3–6]

Early complications are generally related to patient risk factors, catheter tip placement, and the provider technique during catheterization. Such complications therefore present intra-operatively or within 7 days of placement.[7] Mechanical complications, such as catheter damage, occlusion, catheter tip malposition, and migration, are reported to occur in approximately 5% to 19% of patients.[2,8–10] Physical complications including hemothorax, pneumothorax, and arterial puncture, range from 1% to 5%.[11,12] Mechanical and physical complications may be decreased or avoided by recognizing and addressing patient risk factors before catheterization. Factors such as history of failed or multiple catheterization attempts, scarring, abnormal

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anatomy, or the need for catheterization at a site of a previous CVAD all suggest that successful placement may be difficult[13–15] and should be addressed with preoperative imaging or ultrasound-guided placement.

Conversely, late complications such as infectious and thrombotic complications, are related to the presence of the in-dwelling catheter.[2] These types of complications tend to present in a delayed fashion (ie, more than 7 days after placement),[7,16–20] and risk of infection increases with longer catheter dwell time.[21–23] Several studies have recommended against routine or scheduled catheter changes as each replacement increases the risk of subsequent complications.[24,25] It would therefore be reasonable to extrapolate that repeated CVAD placements as a result of infectious or thrombotic-related complications can further increase the risk of placement-related complications.

When selecting a CVAD, available evidence and clinical indications should be used to select the device that most effectively supports the patient's treatment and carries the lowest associated risks.[26] Many evidence-based recommendations and guidelines, mostly for adult patients, exist to aid providers in making these decisions and create the CVAD placement plan that effectively supports the patient's treatment and has the lowest associated risks.[27,28]

The experience in our institution has been that of inconsistent evaluation of patients before central line placement. This can result in the improper device being selected (short peripheral catheter [SPC], midline catheter, peripherally inserted central catheter [PICC], percutaneous non-tunneled CVAD, tunneled CVAD, or implanted port). An inadequate evaluation can result in missed risk factors that can lead to failed access attempts, increase the risk of placement-related complications, or result in the need to cancel the procedure to seek further information for a safe CVAD placement. It is possible that all of these challenges may be reduced or eliminated with a standardized patient evaluation process. Care algorithms are a step-by-step protocol for management of a specific health care problem, with the intent of improving and standardizing decisions made in the delivery of medical care. These algorithms aim to integrate evidence-based recommendations in an efficient and consistent manner. The objective of this quality improvement project was to develop and implement the use of a standardized preoperative evaluation process for pediatric central line placement, based on the known risk of inconsistent preoperative evaluation and the established benefits of care algorithms in improving consistency and patient safety.[29]

METHODS

Setting and Context

This study was performed at a free-standing pediatric hospital, which is an American College of Surgeons–verified surgical center. On average, the institution performs approximately 1600 PICCs and 500 tunneled CVADs/implanted port insertions annually across a vast patient population from routine care to tertiary and quintenary care of some of the most complex pediatric patients. PICCs, midline catheters, and SPCs are placed by the vascular access team nurses, while all other CVADs are placed by surgeons. Interventional radiology (IR) backup is utilized as needed for difficult cases of both PICCs and other CVADs. Safety has been a primary focus at our institution, which has been a member of the Solutions for Patient Safety Network since its inception. Our institution has a mature quality improvement infrastructure, and for this work the team used the Model for Improvement, defined global and smart aims, and then developed a key driver diagram to represent the theory of improvement. For each key driver, the team defined, tested, and refined interventions using Plan-Do-Study-Act (PDSA) cycles.[30–32]

Multidisciplinary Team

A multidisciplinary team composed of a surgeon, vascular access nurse, interventional radiologist, hematologist/oncologist, gastroenterologist, a pediatric surgery advanced practice registered nurse (APRN), a quality improvement consultant, and a data analyst was organized and supported by hospital leadership to standardize preoperative evaluation with the global aim of improving appropriate vascular access device (VAD) selection and safety. The team also sought input from cardiology, anesthesiology, and critical care related to patient risk factors.

Development of Key Driver Diagram

With input from the assembled team, as well as review of existing literature, a key driver diagram was created to drive improvement (Figure 1). Based on the primary key drivers, several interventions were identified and tested.

Development of Care Algorithm

Based on a comprehensive literature review, along with expert opinion of the team, an initial draft of an algorithm was created.[28] The algorithm included information from recent research at our institution that stratified common infusates into risk categories to help determine the safest type of access for infusion (Figure 2).[33] The algorithm was then distributed to all pediatric surgeons and nurse practitioners for review and feedback. Feedback was also solicited from several primary specialty services who routinely request central access for their patients, such as oncologists and gastroenterologists. After several revisions, there was 100% consensus among the attending pediatric surgeons, as well as among the multidisciplinary team members and the pediatric surgery APRNs.

IMPLEMENTATION OF THE GUIDELINE INTERVENTIONS

Education

Small group education sessions, as well as online education, were provided by the lead pediatric surgeon to the house staff team and the pediatric surgery APRNs. Initial

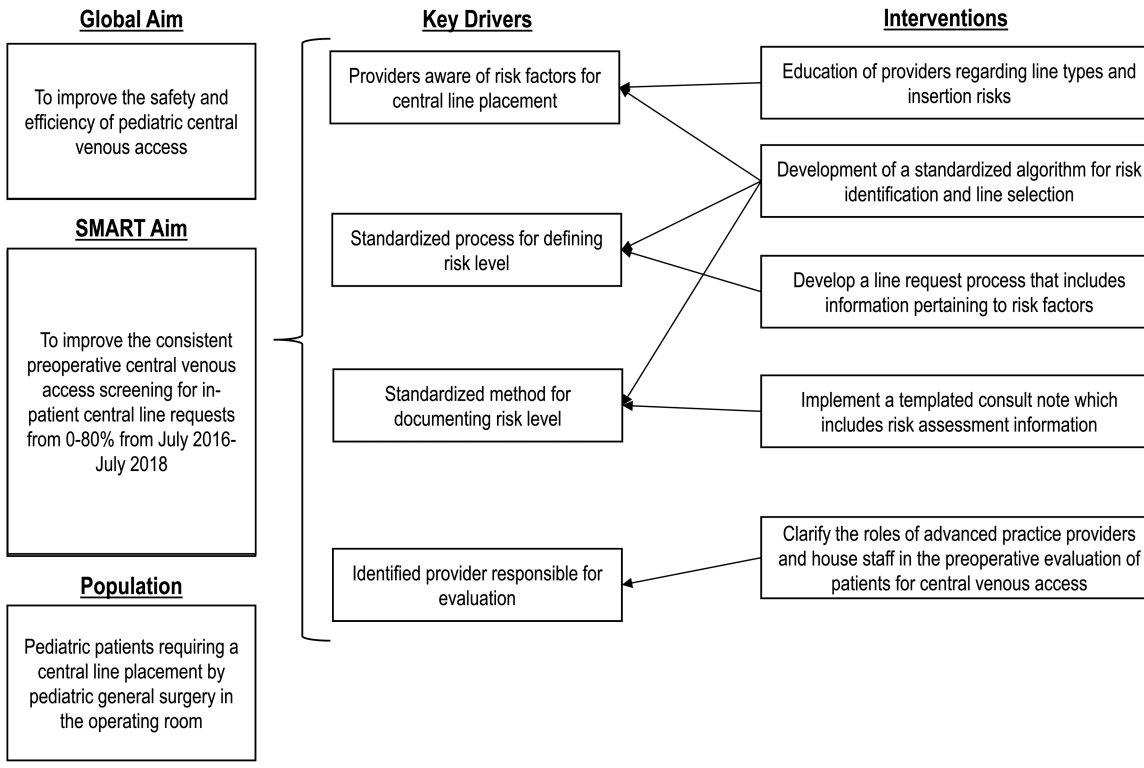

Figure 1 Key drivers for improvement of central line screening procedures.

education provided a basic understanding of central venous access and VAD types for the more junior house staff and APRNs, followed by specific education regarding the use of the care algorithm. Given that house staff rotate on our pediatric surgical service on a monthly basis, the education was ultimately incorporated into their service orientation and included in an existing electronic service handbook. Additional education and discussions were provided to key specialty services across the institution to facilitate understanding and buy-in of the new guideline and process.

Standard Consult Note

A templated consult note was developed in our electronic health record (EHR) with input from our APRN team. This note allowed for standardized documentation, which includes key information that follows the care algorithm and allows for ultimate stratification of the patient into low-, intermediate-, and high-risk groups and outlines additional testing required as necessary.

CVAD Consult Request Order

In order to request a midline catheter, PICC, tunneled CVAD, or implanted port at our institution, it is necessary to complete an order in our EHR. The existing order required a limited amount of basic information. Following development of the care algorithm, the order was updated to include key questions to help select the best VAD choice from SPC through PICC or more traditional central vascular access. In addition, the order was modified to ensure that key information to improve preoperative evaluation and risk stratification was included. Review of this new order was performed by both high utilization services such as oncology and gastroenterology, as well as less frequent utilizers, such as pulmonology and neurology, to ensure clarity. Finally, education and feedback sessions were provided specifically for high utilization areas.

Study of the Improvement

A stepwise approach was utilized to implement each of the above interventions. The initial PDSA intervention was education of a defined cohort of the APRN group. Next, all APRNs and pediatric surgery house staff were educated. Monthly education was also implemented for rotating residents. The next PDSA ramp was the development and modification of a standardized consult note. This was then followed by revision, update, and education related to the central line consult request order.

ANALYSIS

The primary outcome was the successful completion of preoperative screening defined as the patient being categorized into an established risk criterion to facilitate safe preparation and planning. Annotated run charts, created in Microsoft Excel (Microsoft Inc, Redmond, WA), were developed and updated weekly. Neonatal intensive care unit patients and solid organ transplant patients undergoing CVAD placement were excluded from this analysis, as this initial work was not targeted to these specific patient populations with known

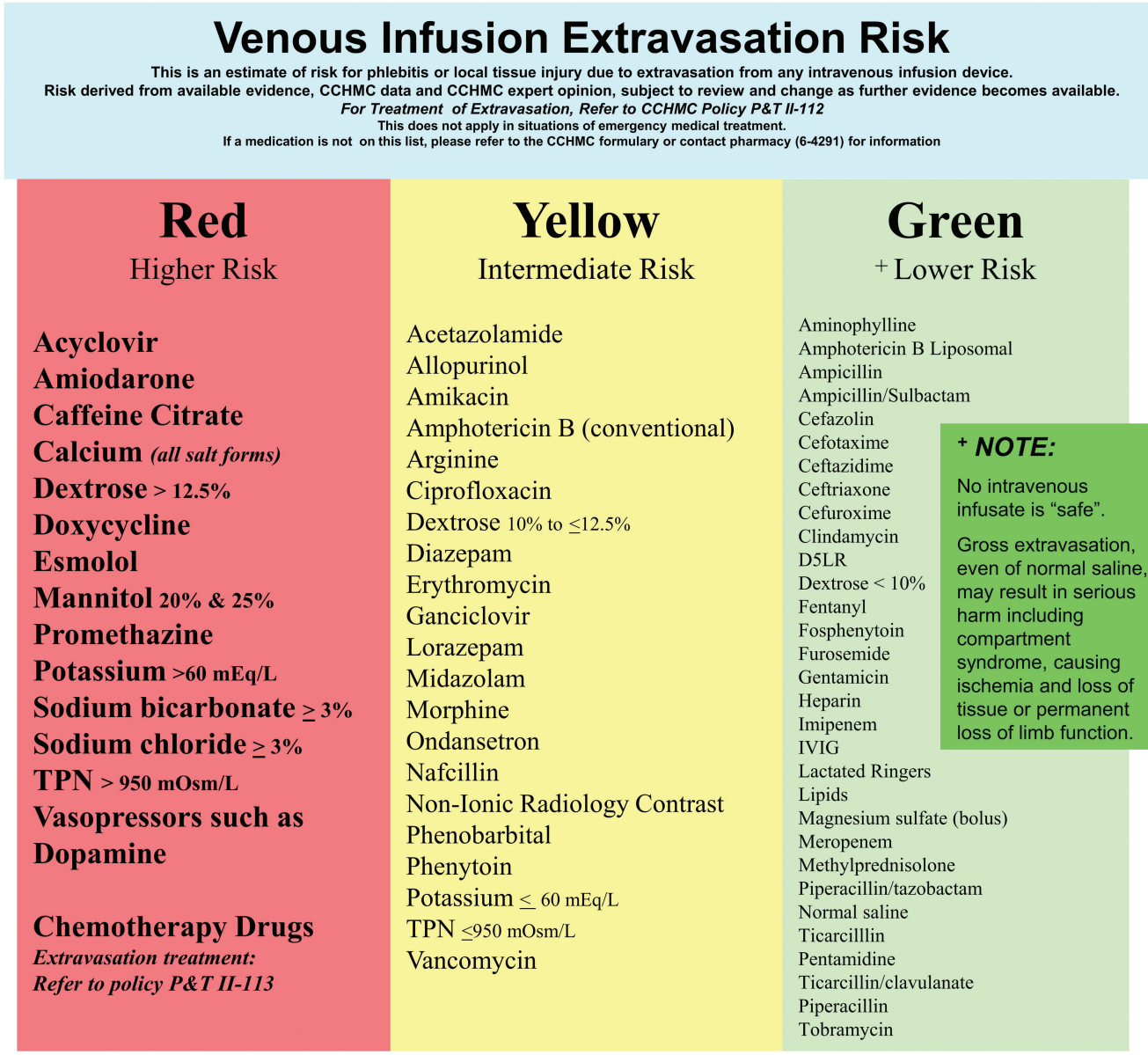

Figure 2 Red-yellow-green system of venous infusion extravasation risk. *Abbreviations: CCHMC, Cincinnati Children's Hospital Medical Center; D5LR, 5% dextrose in lactated Ringer's solution; IVIG, intravenous immunoglobulin; TPN, total parenteral nutrition.*

unique needs and challenges related to vascular access. Simple percutaneous/nontunneled CVAD placements (ie, not apheresis-capable and/or placed prior to major surgery for central access) were also excluded. Standard industry criteria were used to determine whether observed changes were due to random variation or to a specific assignable cause, in this case, our interventions.[34,35] Reasons for non-stratification were investigated and tracked.

RESULTS

Algorithm and Interventions

The multidisciplinary team successfully developed and obtained consensus on an algorithm. The newly developed CVAD care algorithm consists of 3 major parts: VAD selection, patient risk stratification, and preoperative evaluation. VADs are selected based on the anticipated length of treatment and whether the necessary medication or infusate is peripherally compatible or incompatible (Figure 3).[26,27] The first part of the care algorithm determines the most appropriate VAD based on the type of therapy, the duration and frequency of therapy, and the medication's venous infusion risk level (Figure 4). Additionally, this part of the care algorithm redirects patients whose conditions do not specifically require central access or for whom another guideline may be better suited. This includes encouraging the placement of SPCs for patients requiring peripherally compatible infusates or infusions shorter than 14 days and diverting patients with renal failure or end-stage renal disease (ESRD) to a separate ESRD VAD care algorithm. The algorithm uniquely brings advanced practice nurses, vascular access team members,

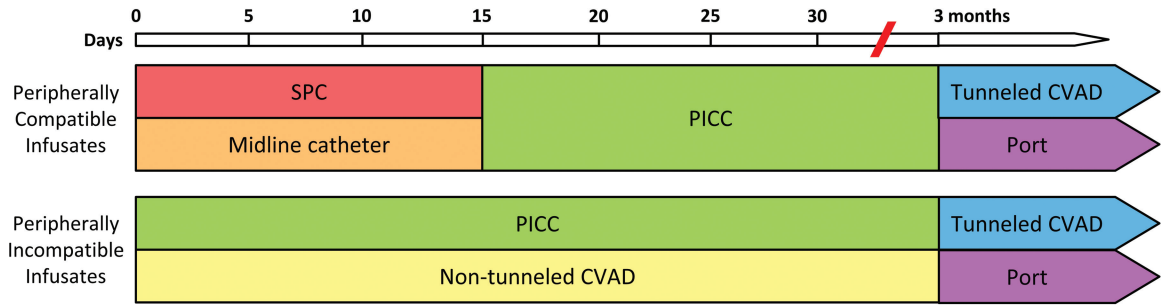

Figure 3 Type of venous access is determined by the anticipated length of treatment and whether the necessary medication or infusate is peripherally compatible or incompatible. *Abbreviations: CVAD, central vascular access device; PICC, peripherally inserted central catheter; SPC, short peripheral catheter.*

interventional radiologists, and surgeons together in evaluation and vascular access placement.

Patients are then stratified into high-, intermediate-, and low-risk categories based on several factors, including prior CVAD placement, history of difficult venous access, history of venous thrombosis, known abnormal venous anatomy or congenital heart disease, low hematocrit, low platelet count, and abnormal body habitus (Figure 5). This section also reinforces that patients who do not specifically require central access should be redirected to a different guideline. Based on the patient's assigned risk level, the next part of the care algorithm determines the need for preoperative imaging, including ultrasound of the great vessels or magnetic resonance venogram, as well as the need for any preoperative treatment, such as wound care, in the site of planned VAD placement or the correction of abnormal laboratory values (Figure 6).

The CVAD care algorithm was initially implemented for inpatients at our institution in April 2016. Following initial education rollout and spread, there was only modest consistency in stratification. Key areas of failure were related to limited access to stratification guideline, limited initial comfort by APRNs in performing central line consults, and lack of consistency/understanding by residents who rotate on the service and evaluate these consults primarily on nights and weekends or when the APRNs are otherwise unavailable. Therefore, in addition to expanding education efforts among both the APRNs and into the basic orientation for new residents, the team looked to incorporate the algorithm into a standard consult template. A specific templated consult note was added to the EHR system in April 2017 that reminds providers to use the care algorithm and walks them through the steps to assign appropriate risk levels (Figure 7). This further improved compliance, but challenges remained secondary to lack of information provided from the requesting service. Based upon this observation, modifications were made to the central line request consult order to also mirror the algorithm and provide online support for VAD selection (Figure 8).

Patient Stratification Data

From April 2016 through September 2018, 871 CVADs were placed at our institution in 654 unique patients. Of these, 376 (43.2%) were inpatients prior to CVAD placement. Among the entire cohort, 33.8% (294) were stratified into preprocedure risk categories over the entire time period. Of the patients who were stratified, 111 were low risk, 75 were intermediate risk, and 108 were high risk. Among all patients, an increase from 0% screening at the beginning of the study period to 58% screening at the end of the study period was achieved (Figure 9A). However, because our current interventions and emphasis was on inpatients, the team focused on this group. As demonstrated in the run chart, the rate of stratification was able to be increased from a baseline of 0% ultimately up to 82% among inpatients only (Figure 9B).

DISCUSSION

Clinical pathways or care algorithms across multiple areas of practice have been safely and effectively implemented and have been shown in the literature to improve patient outcomes and reduce cost.[36–45] Through the collaboration of a multidisciplinary team, a comprehensive pediatric central access screening algorithm was successfully created and implemented. This important algorithm begins with confirming the appropriate type of access required to reduce overuse of surgically placed CVADs, as well as overuse of PICCs when a more suitable long-term VAD would be appropriate. The algorithm ensures that known risk factors for CVAD placement are evaluated in a standard fashion with recommendations for further studies based on the risk stratification level. With the use of the model for improvement effective screening was increased to more than 80% of inpatient children needing a CVAD.

There were many important learning points along the way. First was the importance of bringing diverse viewpoints to the table. In creating our algorithm, aspects that initially seemed clear to those of us on the team responsible for placing VADs were not immediately clear to those who frequently request access for their patients. Specific examples included clarity around VAD types and differences. It was also noted that, at times, those requesting CVAD would refer to VADs by brand name rather than standardized descriptions, such as "tunneled," "non-tunneled," or

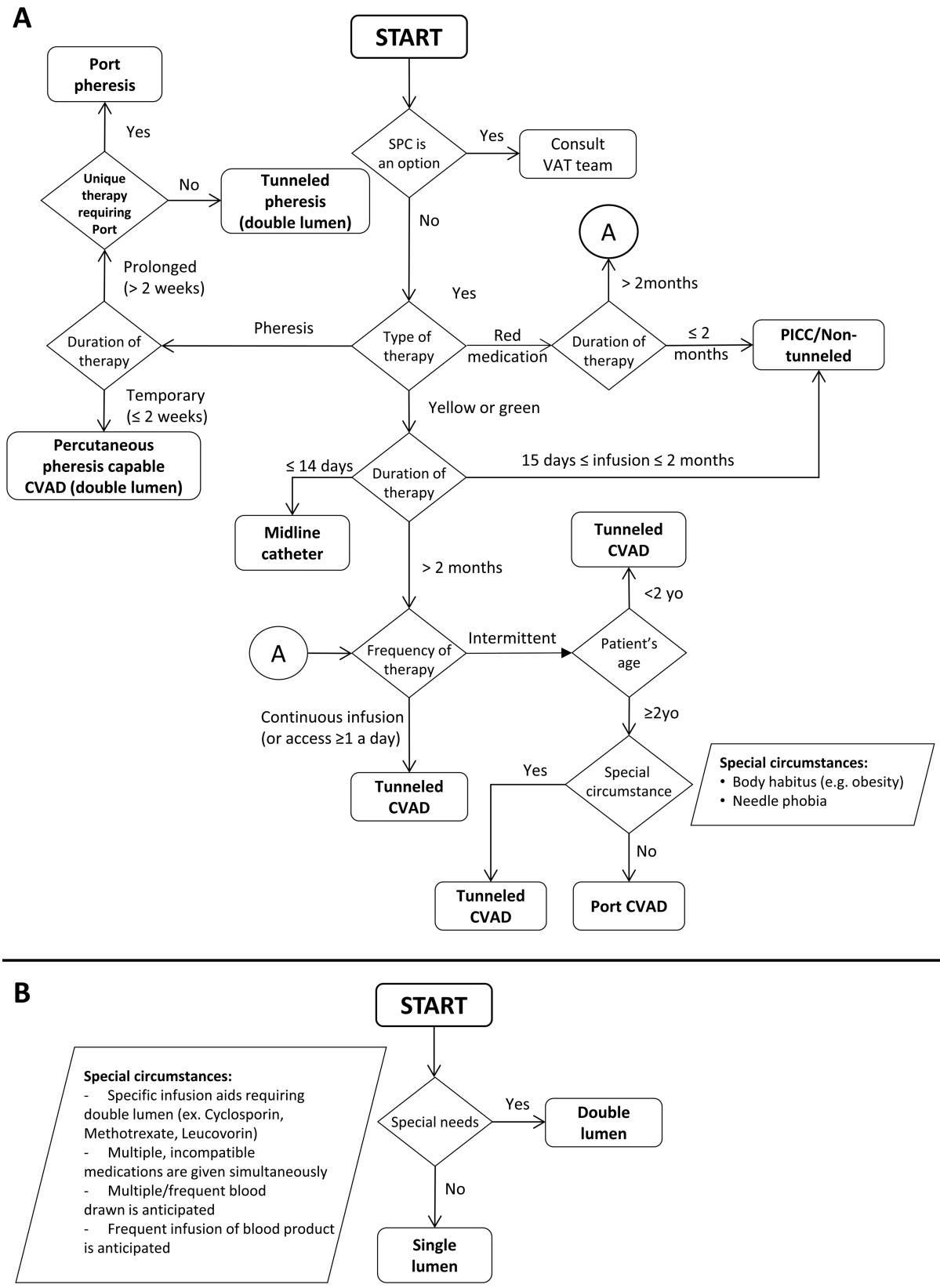

Figure 4 A) Selection guide for the most appropriate type of vascular access device. B) Selection guide for single- versus double-lumen device. *Abbreviations: CVAD, central vascular access device; PICC, peripherally inserted central catheter; SPC, short peripheral catheter; VAT, vascular access team.*

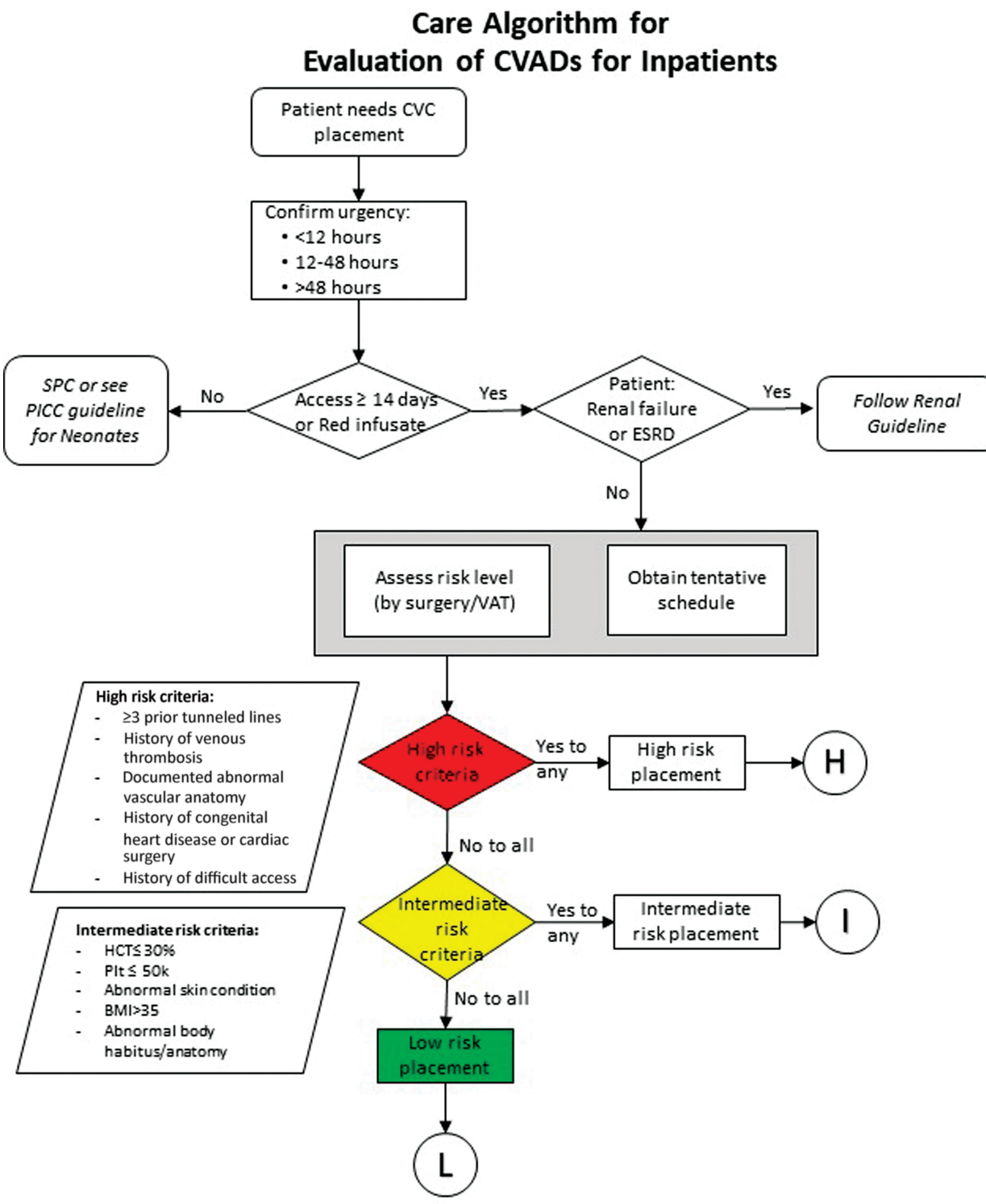

Figure 5 Patient risk stratification for central line placement in inpatients. *Abbreviations: BMI, body mass index; CVAD, central vascular access device; ESRD, end-stage renal disease; HCT, hematocrit; PICC, peripherally inserted central catheter; Plt, platelets; SPC, short peripheral catheter; VAT, vascular access team.*

"implanted port." Next, it was critical to ensure the available evidence was reviewed, as well as obtaining consensus among clinicians who place VADs, that pertinent factors for the preoperative evaluation and the work-up findings are fully evaluated. Finally, the biggest improvement in implementation came only after the development of a standardized consult note and improvements in the electronic request order to help drive evaluation and stratification.

An additional benefit of this work was increased institutional awareness and engagement in standardization around central venous access. As with many institutions, there are a host of providers across the system involved

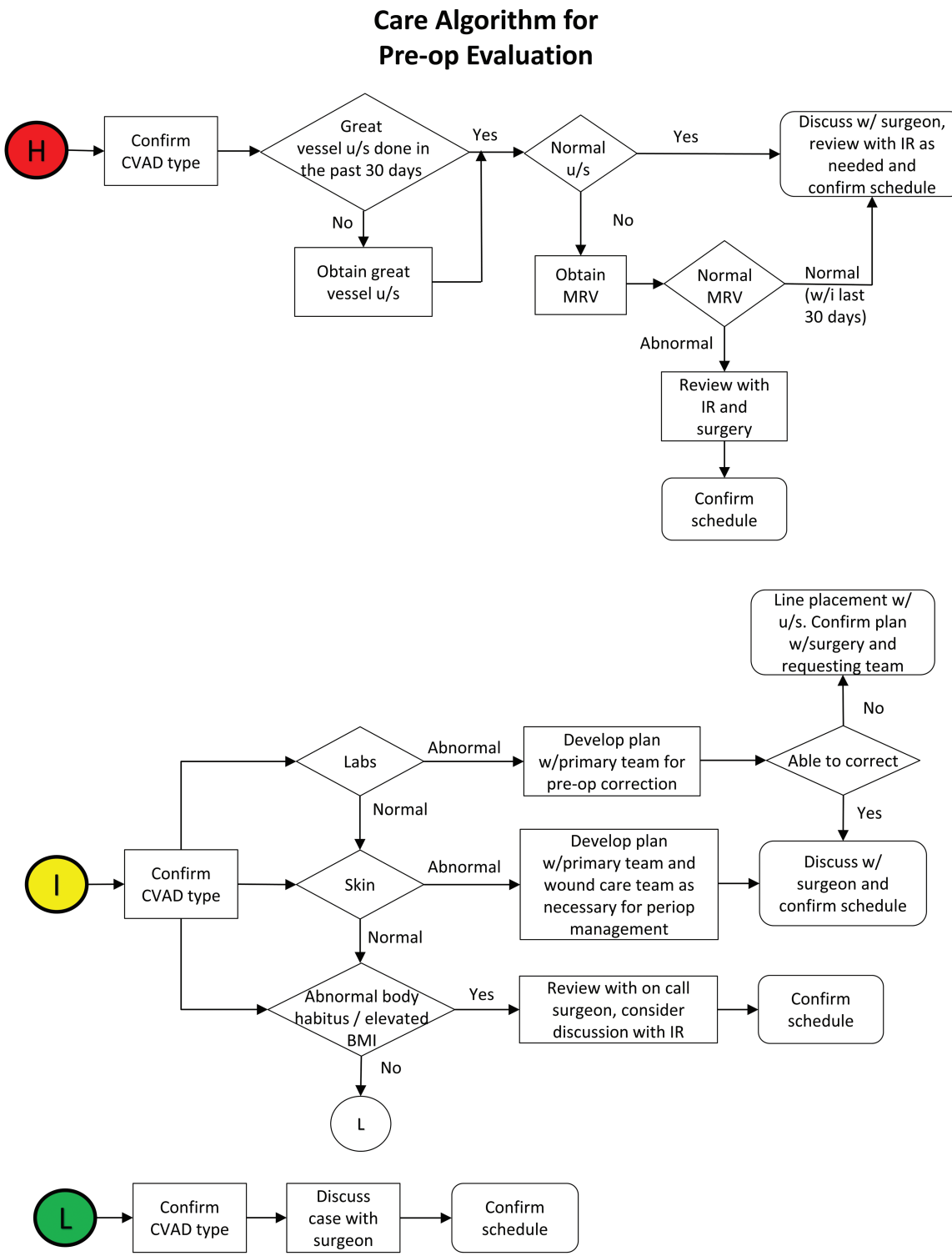

Figure 6 Recommended preoperative evaluation by patient risk stratification group. *Abbreviations: BMI, body mass index; CVAD, central vascular access device; IR, interventional radiology; MRV, magnetic resonance venography; u/s, ultrasound.*

with requesting CVADs, catheter insertion, reducing central line-associated blood stream infections (CLABSI), and maintaining an adequate supply of catheters. Based on the engagement in this work, an institutional vascular access committee was formed. The committee includes representation from general surgery, IR, hematology/oncology, gastroenterology, neonatology, vascular access nursing team, critical care physicians, supply management, and leadership for the institutional CLABSI work. The work of this committee has resulted in a house-wide standardization of CVAD products utilized both in the operating room and in the critical care units. This standardization has reduced our overall supply, led to consistency in the use of sharps safety devices, and allowed for improved communication among

History of Present Illness: NAME is a AGE SEX who is being seen for central line insertion for {Indications:30480399}

Urgency of Line Access: {URGENCYLIST:304302182}

Coordination with other procedures needed: {YES***/NO:26349}

Duration Line Needed: {time period:210503589}

Type of Line Requested: {CVCINSERTLINETYPE:304302183} {DEVICES; CATH # OF LUMENS:30452011}
If Mediport does it need accessed: {YES/NO/NOT AP:29489}
If Apheresis/Dialysis line does it need to be tunneled: {YES/NO/NOT AP:29489}

Current Access:

Patient Lines/Drains/Airways Status

Active Lines

Name:	Placement date:	Placement time:	Site:	Days:
PIV Right Antecubital 04/29/20 1622	04/29/20	1622	Antecubital	less than 1

Prior Line Difficulty/Complications: {YES***/NO:26349}
Any prior IV lines: {YES***/NO:26349}

1. {iv access:30470598}, {DATE; MONTH:304900063}{Location on body:14304:x}
2. {iv access:30470598}, {DATE; MONTH:304900063}{Location on body:14304:x}
3. {iv access:30470598}, {DATE; MONTH:304900063}{Location on body:14304:x}
4. {iv access:30470598}, {DATE; MONTH:304900063}{Location on body:14304:x}

A

ASSESSMENT
NAME is a AGE SEX with need for central line insertion for {Indications:30480399}

Risk stratification: {RISKCATEGORY:304302184}

Low Risk

Intermediate Risk: HCT < or = 30
Plt < or = 50k
Abnormal skin condition
BMI > 35
Abnormal body habitus/anatomy

High Risk > or = 3 prior lines
History of venous thrombosis
Documented abnormal vascular anatomy
History of congenital heart disease or cardiac surgery
History of difficult access

PLAN

Antibiotics to be on-call - ***
Hct goal >25-30
Plt goal >60
Please transfuse as indicated and recheck
Replace electrolytes as needed and recheck for anesthesia
Imaging studies as indicated if High Risk (ultrasound, CT angiogram, MRI) and consider consulting Interventional Radiology
- If needed for prior access
- hx of access difficulty
- hx of 3 or more central lines
- hx of thrombus
- dialysis patient

B

Consent placed on chart for attending and patient/caregiver signature.

Figure 7 Excerpts from the templated central line consult note. A) The patient history portion of the note includes smartblocks for type of access needed as requested by the consulting provider. Also included is a section for listing prior central access to help determine which risk category the patient is. B) The assessment and plan portion of the note includes a smartphrase for patient risk stratification, with criteria listed for high-, intermediate-, and low-risk categories. Additional imaging studies or consults are requested if the patient meets high-risk criteria. *Abbreviations: BMI, body mass index; CT, computed tomography; CVAD, central venous catheter; HCT, hematocrit; hx, history; IV, intravenous; MRI, magnetic resonance imaging; PIV, peripheral intravenous catheter; Plt, platelets.*

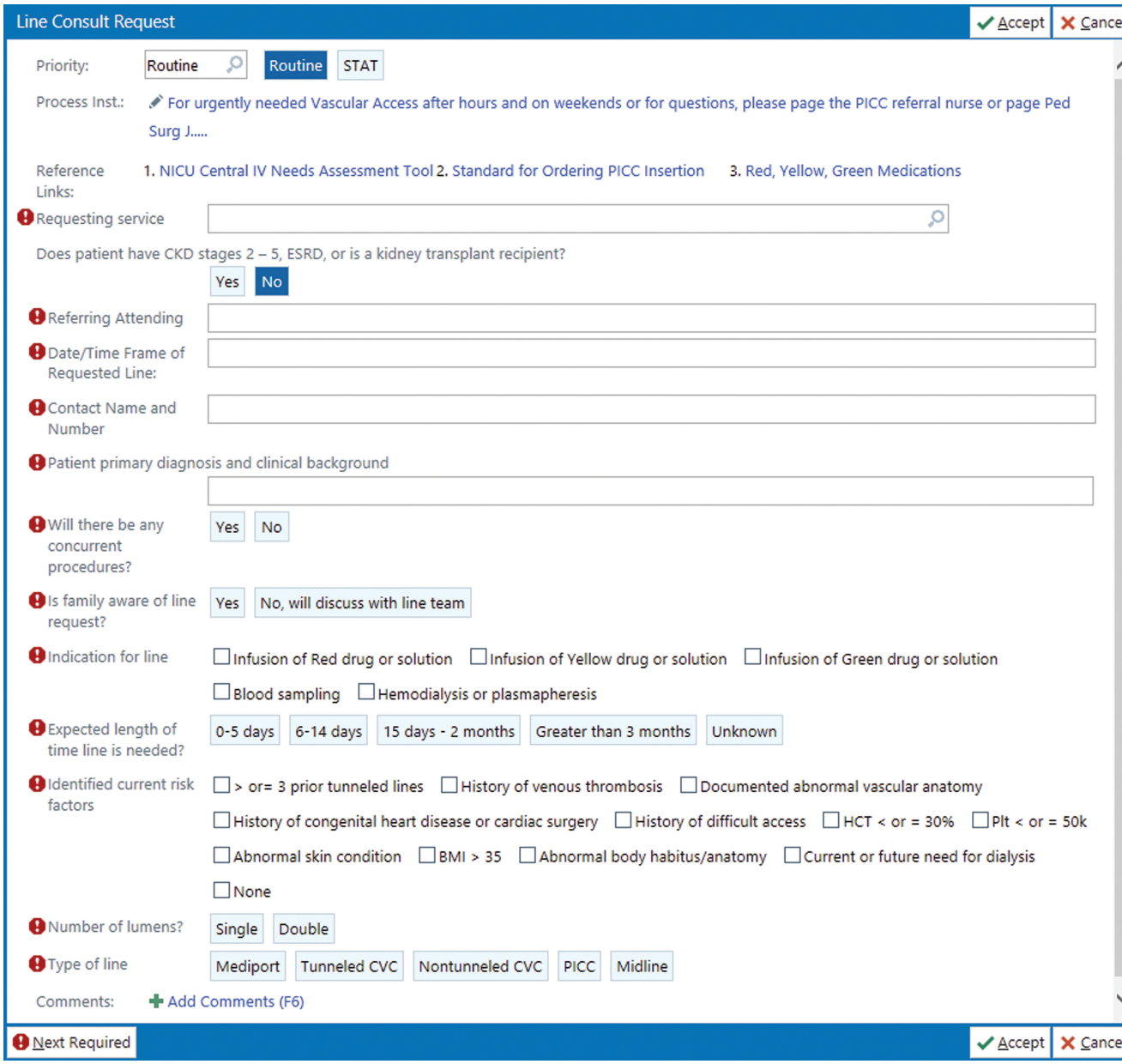

Figure 8 Central access consult order. The second field is a hard stop to divert patients with ESRD, as those patients will follow the renal guideline (not discussed in this article). The requesting provider is required to include demographic data, as well as scheduling considerations and type of CVAD requested. Additionally, the provider must identify current patient risk factors. *Abbreviations: BMI, body mass index; CKD, chronic kidney disease; CVAD, central venous catheter; ESRD, end-stage renal disease; HCT, hematocrit; IV, intravenous; NICU, neonatal intensive care unit; PICC, peripherally inserted central catheter; Plt, platelets.*

providers regarding CVAD choices. In addition, this committee has helped ensure the spread of standardized pre- and post-CVAD placement timeouts. The work has now expanded to include standardization around selection of catheters for patients with ESRD and the decision-making process for tunneled line removal.

LIMITATIONS

A key limitation of the work at this stage is that verified reductions in complications have not yet been demonstrated. This phase of our work was specifically to develop and implement the algorithm, accepting that long-term follow-up will be needed to demonstrate significant clinical impact. Although evidence would support that better preoperative evaluation and planning should reduce unplanned events – including last-minute cancellations, VAD choice changes, or technical complications including inability to obtain access – this initial work has been focused first on development and implementation of the algorithm. Reported early complication rates for CVADs (within 7 days of placement) range from 4% to 7%.[12,46] At our institution, the rate has historically been around 6%. Given the overall

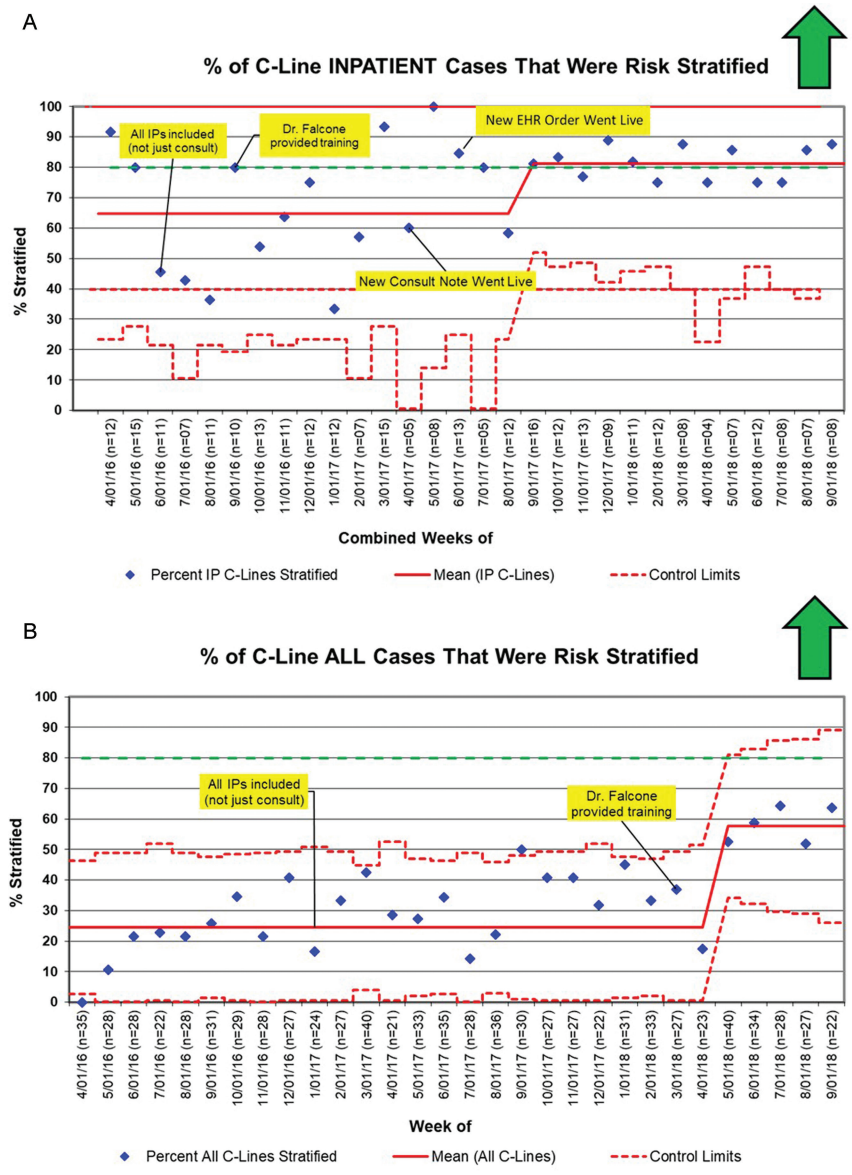

Figure 9 Percentage of central line consult patients who were risk stratified prior to line placement from April 2016 to September 2018. A) Monthly stratification data for all patients. B) Monthly stratification data for inpatients only. *Abbreviations: CVAD, central vascular access device; EHR, electronic health record; IP, inpatient.*

low incidence, it will take prolonged evaluation to identify a reduction. The authors also do not yet have sufficient data to show a reduction in last-minute case cancellations due to inadequate preoperative evaluation, although feedback from providers does suggest this.

An additional limitation of this quality improvement project is that the team has primarily concentrated on the evaluation of patients who are in the hospital prior to their CVAD placement, while nearly two thirds of the CVADs placed are for outpatients. Although this population is generally healthier and lower risk, many have had multiple prior CVADs or other physiologic findings that increase risk without proper preoperative planning. The work has now expanded the focus on the outpatient population. Finally, the risk stratification categories developed were based on both evidence in the literature as well as expert consensus. Although the authors saw an expected distribution across categories, there are not specific enough data at this point to demonstrate the specific complication risk differences in these groups or the impact of the algorithm that may have blunted the risk through improved planning.

CONCLUSION

Overall, the development of the CVAD care algorithm effectively and comprehensively integrates the existing literature and recommendations for safe and effective CVAD placement. The care algorithm addresses risk factors for the most common types of CVAD complications and is generally effective at identifying patients who require

preprocedure imaging, labs, or other considerations. As the implementation and usage of the care algorithm increases, aided by an automated EHR template, it is likely that the placement-related complication rate will decline. Future directions with this work will focus on improving the outpatient screening process, analyzing the data regarding improved safety and efficiency, possibly modifying risk categories to better characterize these patients, and implementing automated screening based on the consult request order and information from the EHR.

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