Catheter-Associated Blood Stream Infections in Intracardiac Lines

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Abstract

Purpose Right atrial (RA) or intracardiac lines are commonly used for hemodynamic monitoring in children undergoing cardiac surgery. In some institutions, these lines are used as the preferred long-term access line due to concerns for catheter-associated blood stream infections (CABSI) and catheter-related venous thrombosis with central lines in other locations. However, the rates and risk factors for CABSI and other complications are not known for RA lines. We undertook this study to estimate CABSI rates for RA lines in comparison with central catheters of various types and locations and to evaluate the incidence of other complications associated with the use of RA lines.

Methods After approval from the Institutional Review Board, a retrospective review of all patients undergoing cardiac surgery at Arkansas Children's Hospital between the dates of January 1, 2006 and December 31, 2011 was performed. Demographic data, clinical features, and outcomes were summarized on a per-patient level. Type, location of placement, and duration of all centrally placed catheters as well as associated complications were recorded. Central venous lines (CVL) used in our unit include peripherally inserted central catheters (PICC) lines, and antibiotic and heparin coated double or triple lumen lines placed in internal jugular (IJ), femoral (Fem), or RA positions. The data were analyzed using statistical software STATA/MP.

Results A total of 2,736 central lines were used in 1,537 patients. Data on line duration, alteplase use, and percentage of lines developing CABSI are described in the study. Disease severity as assessed by risk-adjusted classification for congenital heart surgery (RACHS) score ($p < 0.046$), year of placement ($p < 0.001$), and line type adjusted for thrombolytic (alteplase) use are significantly associated with risk of any CABSI. Overall, IJ and RA lines had least risk of CABSI while PICC lines had the highest CABSI rates. RA lines are also associated with other medically significant complications.

Conclusion The CABSI rates associated with RA lines are lower than those seen with PICC lines. However, RA line use is associated with other, potentially significant complications. RA lines may be used cautiously as long-term access lines in cardiac patients in whom it is important to preserve venous patency for future interventions.

Keywords

- ▶ alteplase
- ▶ intracardiac lines
- ▶ right atrial lines
- ▶ peripherally inserted central catheters
- ▶ catheter-associated blood stream infections
- ▶ risk-adjusted classification for congenital heart surgery

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The role of transthoracic intracardiac monitoring lines in patients undergoing corrective and palliative procedures for congenital or acquired cardiac disease has been well established, and they are used routinely for this purpose in many institutions, in combination with neck or femoral central venous catheters^{1,2}. They are also being increasingly used as additional central access in patients, especially in neonates with complicated intraoperative or prolonged postoperative course, in patients with single ventricular physiology undergoing palliative surgeries, or those undergoing cardiac transplantation requiring prolonged operative courses. Occlusion of central veins can be especially problematic in these groups of patients as it can limit future surgical or catheter-based interventions.^{2,3}

Catheter-associated blood stream infections (CABSI) are an important cause of morbidity and mortality in pediatric cardiac intensive care units. Infection rates are known to be higher in nonantibiotic coated catheters, catheters with more than one lumen, receipt of blood transfusion, receipt of parenteral nutrition, location, and duration of catheter placement, presence of gastrostomy tube, and cardiac diagnoses.⁴⁻⁶ Additionally, catheter-related thrombosis has also been noted to be related to the development of CABSI.⁷⁻⁹

Other medically significant complications can be associated with any location of invasive monitoring, which includes bleeding, thrombus formation, vascular occlusion, cardiac tamponade, and catheter nonfunction. These complications are frequently avoidable and can be safely managed if recognized early and treated aggressively.^{10,11}

The rates of CABSI and the associated risk factors in right atrial (RA) lines are not known. We therefore undertook this study to estimate CABSI rates for RA lines in comparison with various other catheter types and locations of placement. We also collected data to better understand the incidence of other complications associated with the use of RA lines.

Methods

Subjects

After approval from the Institutional Review Board, a retrospective review of all patients undergoing cardiac surgery at Arkansas Children's Hospital between the dates of January 1, 2006 and December 31st 2011 was performed. The hospital records of each child were reviewed and pertinent data were extracted. Consent was waived because this was a retrospective study and no additional procedures or interventions were performed as a result of this study. The study included all postoperative cardiothoracic surgery patients, with any type of CVL placed preoperatively and/or intraoperatively and who were admitted to the cardiovascular intensive care unit (CVICU) at Arkansas Children's Hospital after surgery. RA lines were placed at the surgeons' discretion, usually in patients in whom they anticipated that a CVL may be required for more than a short period of time in the postoperative period. No patients with transthoracic intracardiac catheters were excluded.

Data Collection

Variables on demographic characteristics, the type of monitoring catheter implicated, and the specific physiological state of each patient, age, diagnosis, type of surgical procedure, disease severity as assessed by risk-adjusted classification for congenital heart surgery (RACHS), year of line placement, use of alteplase, as well as other complications were collected.

Demographic data, clinical features, and outcomes were summarized on a per-patient level. Type, location, and duration of all centrally placed catheters as well as associated complications were recorded. CVLs used in our CVICU include the following: PICC lines and antibiotic coated double or triple lumen catheters placed in IJ, Fem, or RA positions.

Institutional Methods

All RA lines were placed in the operating room before separation from the cardiopulmonary bypass (CPB) circuit (or prior to chest closure in non-CPB cases). All lines were placed under sterile conditions, placement was confirmed with an X-ray, and all lines were sutured to the skin. Patients were followed from the time of surgery through their entire stay. While the catheters were in place and after catheter removal, general hemodynamics (systemic arterial pressure, atrial pressure, heart rate, and oxygen saturation) were monitored continuously. Coagulation data, if available, were obtained before catheter removal.

Study Definitions

Catheter-associated morbidities can occur during its use, while in the intensive care unit (ICU) (including infection, catheter nonfunction, thrombus formation), and after catheter removal (including bleeding, catheter retention, need for intervention, and hemodynamic instability). Bleeding was considered present when it led to hemodynamic instability, or an echocardiogram showed pericardial effusion with tamponade physiology.

At our institution, catheters were considered nonfunctional when they could neither be infused through nor aspirate blood from. Thrombus formation was considered to have occurred when there was evidence of right atrial thrombus on echocardiogram. A catheter was considered infected only if cultures obtained from the catheter were positive for identified organisms.

Disease severity as assessed by RACHS score was calculated in all patients.¹² Surgical procedures were classified into six risk categories, making it possible to compare the groups. RACHS was applied to all cases of surgery for congenital heart disease in our study sample. It relied on variables such as surgical procedure and age. Patients without congenital heart disease, but underwent heart surgery, were identified in our sample as not scored (pacemaker, heart transplant, redo-transplant, and ventricular assist devices).

Statistical Analysis

All the data were analyzed using statistical software STATA/MP v13.1 (StataCorp LP, College Station, TX) and R v3.1.1 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were expressed as median (first quartile to third quartile), and range for continuous variables, and count (percentage %) for categorical variables. The distribution of continuous variables and the proportions of categorical

variables were compared among different line types using the generalized linear mixed models with gamma distribution and binomial distribution, respectively. The models considered the correlated lines from the same admission. To investigate the risk factors for line infection, a Frailty model was fitted for time-to-infection as a function of weight, age, gender, race, RACHS-I score category, year, CV line type (CVL Femoral, CVL IJ, RA, PICC), and use of alteplase (yes or no). The correlated lines from the same admission were taken into account when fitting the Frailty model. Kaplan–Meier curves were plotted for freedom from line infection. Log-rank tests were performed to evaluate the difference in Kaplan–Meier curves among different line types. *P* values less than or equal to 0.05 were considered to indicate statistical significance.

Results

A total of 2736 lines were used in 1537 patients in our CVICU from 2006 to 2011. The demographic and clinical characteristics are shown in ►Table 1. Survival to discharge was 94%. PICC lines and RA lines tended to stay longer compared with IJ and Fem CVL ($p < 0.001$). The likelihood of developing a CABS was the highest in PICC line ($p < 0.001$) (►Table 2). The likelihood of alteplase use was highest with PICC lines, although this was not statistically significant ($p = 0.08$). A repeated event Cox regression model to evaluate the risk for developing CABS showed that the risk was significantly lower in patients with noncategorized RACHS diagnoses (heart transplants, pacemakers, etc.) ($p < 0.046$) and decreased over the years during the study period ($p < 0.001$) (►Table 3). The risk of developing a CABS was significantly lower in RA catheters when compared with PICC catheters ($p < 0.002$) (►Figs. 1A and B).

We excluded 60 CVLs from the study secondary to not knowing the specific location of insertion. In addition to CABS, RA catheters are associated with other complications as shown in ►Table 4.

Discussion

RA lines are commonly used in children undergoing cardiac surgery for hemodynamic monitoring. They are being increasingly used at some centers for longer term central access in patients undergoing complex cardiac procedures.² This study provides a contemporary overview of infections and other complications and morbidities associated with the use of RA catheters in children. It is the first study to provide data on RA line associated CABS and shows that these rates are lower than CABS rates associated with PICC lines, even though both have similar median duration of use (13 days versus 16 days, $p < 0.001$). Our study also confirmed previously published findings of an association between development of CABS in catheters that had previously required alteplase for nonfunction or thrombosis.⁹ We also found a low, but clinically significant, rate of other serious complications with use of RA lines, which confirms previously published experience from other centers^{1,2}.

Table 1 Demographics

N = 1537 admissions	
Gender	
Female	662 (43%)
Male	872 (57%)
Missing	3
Race	
Black	372 (24%)
Caucasian	1020 (66%)
Hispanic	90 (6%)
Other	16 (1%)
Age at surgery	
Median (Q1, Q3)	213 days (38 days–4.4 years)
Range	1 day–17 years
Weight (kg)	
Median (Q1, Q3)	7.1 (3.8, 18)
Range	1–126
RACHS Score	
Not Scored	317 (21%)
1–2	496 (32%)
3–4	654 (43%)
5–6	70 (5%)
Lines Observed	
Median (Q1, Q3)	1 (1, 2)
Range	1–15
Lines Observed (Freq)	
1	817 (53%)
2	498 (32%)
3	121 (8%)
4	51 (3%)
More than 4	52 (3%)
Death	84 (6%)
Discharged	1442 (94%)
Missing	11

Abbreviation: RACHS, risk-adjusted congenital heart surgery score.

At our institution, PICC lines are placed postoperatively in children if they require long-term central access and do not have RA lines in place. PICC lines are not heparin or antibiotic coated and are placed under ultrasound guidance by interventional radiology. Insertion and maintenance of all lines, including PICC lines, is done in the same manner (insertion using sterile technique and maximal barrier precautions and line maintenance with sterile dressing change and chlorhexidine scrub). However, the mean duration of PICC lines was statistically significantly longer compared with RA lines (25.1(29.6) days versus (20.8(23.3) days; $p < 0.01$).

Table 2 Summary by line type

	PICC	CVL jugular	CVL Femoral	RA	Total	p value
Subjects (Unique MRs)	247	771	559	553	1243	
Admissions	274	869	615	653	1526	
Total lines	311	922	712	731	2676	
Total line days	7797	7451	8634	15203	39085	
Total infections	32	15	20	30	97	
Total lines having at least one infection	31	15	19	27	92	
Lines having at least one Infection (f/c)	10%	1.6%	2.7%	3.7%	3.4%	<0.001
Mean infections per 1000 line days (e/d)	4.1	2	2.3	2	2.5	
Alteplase use						
No	60 (19%)	407 (44%)	230 (32%)	223 (31%)	920 (34%)	0.08
Yes	251 (81%)	514 (56%)	481 (68%)	507 (69%)	1753 (66%)	
Line duration (days)						
Mean (SD)	25.1 (29.6)	8.1 (11.4)	12.1 (15.2)	20.8 (23.3)	14.6 (19.9)	<0.001
Median	16 (8 to 32)	5 (3–8)	8 (5–14)	13 (7–24)	8 (4–17)	
Range		1–282	1–168	1–242	1–176	1–282

Our study confirms that the incidence of CABSIs is dependent on the duration of retention of central lines^{5,6}. We were also able to confirm that the incidence of CABSIs in our CVICU is higher in femoral and PICC catheters when compared with RA and IJ catheters.

This reduced risk of developing CABSIs makes RA catheters a better option for use as long-term catheters in patients in whom a complicated postoperative course is anticipated. However, the presence of serious morbidities associated with its use (►Table 4) complicates this decision. Some of these morbidities have also been described by Flori et al in their description of intracardiac lines used at their center.²

Catheter thrombosis is now well recognized as a risk factor for the development of CABSIs.^{8–10} In our study, alteplase was seen more frequently used in PICC lines. It is not clear if this difference is due to the material composition of these catheters (silastic versus polyurethane), the location of these catheters (upper extremity versus neck or femoral region), or if there are some other factors that may explain this difference. Certainly, the longer mean duration of PICC lines could have played a role in thrombosis development also.

Our study has several limitations. This is a single center, retrospective analysis. During the study period, the incidence of CABSIs decreased in our cardiac ICU due to a concerted effort by our unit on becoming a part of the National Association of Children's Hospitals and Related Institutions (NACHRI) collaborative to reduce CABSIs rates in pediatric ICUs. As part of this effort, we implemented insertion and maintenance bundles and two additional interventions (chlorhexidine scrub and chlorhexidine sponges). The details of these interventions are previously published by Miller et al.³ The impact of this collaborative on our practices probably drove us in the

direction of retaining RA lines preferentially compared with other forms of central access to continue to lower CABSIs rates.

While we were able to capture some of the significant complications that occurred in patients with RA catheters from our medical records, it is possible that some less significant effects (such as fibrin sheaths in the RA) may have not been captured due to incomplete documentation. Additionally, complications associated with other catheters, other than infections, are harder to capture as they are not routinely documented at our center and we do not routinely perform ultrasound or angiograms to look for vessel occlusion, which can become a major subsequent concern. The lack of data capture regarding noninfectious complications associated with CVLs, especially those thought to be minor complications such as thrombosis, remains an important limitation of our study.

Many patients had multiple lines at the same time. For example, the same patient had a RA, IJ, and/or femoral catheter at the same time for clinical management purposes. We attributed a positive blood culture in such cases to the lumen that the blood culture was drawn. However, it is possible that the CABSIs in such a case was actually related to the other catheter.

Conclusion

RA lines have a lower rate of CABSIs compared with PICC lines when used for long-term access. The CABSIs rates associated with RA lines were similar to rates seen with IJ catheters. There was a trend toward association between alteplase use and development of CABSIs, but this trend was not statistically significant. RA catheters are also associated with a low but

Table 3 Results from frailty model of bloodstream infection

	Adjusted Hazard Ratio (95% CI)	p value
Weight (kg)		
10.5 (kg) increase	1.0 (0.78, 1.3)	0.99
Age (years)		
3 year increase	0.94 (0.74, 1.2)	0.65
Gender: Male vs Female	0.90 (0.58, 1.4)	0.62
Race		<0.001
Black vs Caucasian	1.2 (0.78, 2.0)	0.63
Hispanic vs Caucasian	0.72 (0.28, 1.8)	0.49
Other vs. Caucasian	0.01 (0.00, 0.01)	< 0.001
RACHS-I		0.18
Unscored vs 5–6	0.45 (0.21, 0.99)	0.046
1–2 vs 5–6	0.50 (0.19, 1.31)	0.16
3–4 vs 5–6	0.71 (0.35, 1.43)	0.34
Year		<0.001
2007 vs 2006	0.85 (0.45, 1.63)	0.63
2008 vs 2006	0.50 (0.26, 0.95)	0.034
2009 vs 2006	0.58 (0.30, 1.12)	0.11
2010 vs 2006	0.33 (0.16, 0.69)	0.003
2011 vs 2006	0.001 (0.001, 0.003)	<0.001
CVL line		0.023
CVL Fem vs CVL Jug	0.68 (0.34, 1.36)	0.28
PICC vs CVL Jugular	1.32 (0.72, 2.45)	0.37
RA vs CVL Jugular	0.51 (0.25, 1.03)	0.061
RA vs CVL Femoral	0.75 (0.44, 1.27)	0.28
PICC vs CVL Femoral	1.94 (1.10, 3.45)	0.023
RA vs PICC	0.39 (0.21, 0.71)	0.002
Alteplase use:		
Yes vs. No	1.4 (0.76, 2.6)	0.28

Note: Between the exclusions (missing data on predictors and excluded because infections could not be attributed to a particular line and fewer cases), there weren't many infections for 2011.

clinically significant rate of other complications. However, no conclusions can be made with any confidence about the noninfectious complications of CVLs in our patients due to lack of comprehensive data. We cautiously support the use of RA lines in pediatric cardiac surgical patients for hemodynamic monitoring and long-term central access due to lower risk of developing CLABSI.

Conflict of Interest
None.

Fig. 1 (A) Kaplan–Meier plot of freedom from line infection, stratified by CV line type for lines with alteplase. Truncated at 90 days. (B) Kaplan–Meier plot of freedom from line infection, stratified by CV line type for lines without alteplase. Truncated at 90 days.

Table 4 Complications

RA line complications	N	Number of RA lines	Percent RA lines with complications (N/731)
Stroke	2	731	0.27%
Tamponade	1	731	0.14%
Fibrin sheath	22	731	3.01%
Cardiac arrest postline removal	1	731	0.14%
Hemorrhage	3	731	0.41%
Pericardial effusion	21	731	2.87%
RA thrombus	16	731	2.19%
Pleural effusion	4	731	0.55%
Other	7	731	0.96%

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