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Submission template

TITLE OF CASE
Substantial harm associated with failure of chronic paediatric central venous access devices

SUMMARY

Central venous access devices (CVADs) form an important component of modern paediatric healthcare, especially for children with chronic health conditions such as cancer or gastrointestinal conditions. However device failure and complications rates are high.

Over two and a half years, a child requiring parenteral nutrition and associated vascular access dependency due to 'short gut syndrome' (intestinal failure secondary to gastroschisis and resultant significant bowel resection), had nine CVADs inserted and these subsequently fail. This resulted in multiple anaesthetics, invasive procedures, injuries, vascular depletion, interrupted nutrition, delayed treatment and substantial healthcare costs. A conservative estimate of the institutional costs for each insertion, or re-wiring, of her tunnelled CVAD was AUD$10,253 (2016 dollars).

These complications and device failures had significant negative impact on the child and her family. Considering the commonality of conditions requiring prolonged vascular access, these failures also have a significant impact on international health service costs.

BACKGROUND

Central Venous Access Devices (CVADs) are an essential component of short and long-term care provision for ~50,000 children in Australia, and millions of children internationally.[1, 2] Despite their necessity, one in four of these devices is associated with a severe complication and fails prior to completion of treatment.[3] These rates of CVAD failure, in addition to higher rates of complications that resolve after interventions, are unacceptable, and place an enormous burden on the healthcare system, children and families.

For children with chronic health conditions, and dependence upon vascular access for nutrition and treatment, device failures substantially reduce morbidity, quality of life and longevity.[4] However seminal literature and international guidelines[5-7] are principally focussed on the prevention of only infectious complications, despite the higher prevalence of other types of CVAD dysfunction.[3] Mechanical and vascular injuries associated with CVADs, such as venous thrombosis, are critical. Each result in treatment disruption, additional resources and difficulty associated with replacement CVAD insertion, morbidity and long term vessel depletion.[3, 8] Vessel depletion further seriously impacts on the health and well-being of children who have a life-long dependency on vascular access, and existing chronic conditions such as immune-compromised or malabsorption nutritional disorders.[4]

A demonstration of the burden and harm associated with CVADs for children with chronic, vascular access dependent conditions is not evident in the literature. With consent from the legal guardian, a case study has been used to illustrate the current complex and harmful experience of paediatric CVAD dependency and failure. The case study also explains the local resources wasted due to potentially preventable adverse events associated with ineffective paediatric CVAD practices.

CASE PRESENTATION

The child was born in an Australian tertiary referral hospital in June 2014 with gastroschisis. After early surgical repair, she required significant bowel resection (15cm, including the ileocecal valve), resulting in short bowel syndrome (or intestinal failure), and a long term dependency upon parenteral nutrition (PN). While the child's treatment nutritional goal is enteral autonomy, she is currently heavily dependent on vascular access for the safe administration of parenteral nutrition, and is likely to remain so for the foreseeable future.

INVESTIGATIONS *If relevant*

NA

DIFFERENTIAL DIAGNOSIS *If relevant*

NA

TREATMENT *If relevant*

NA

OUTCOME AND FOLLOW-UP

By two and a half years of age, she has had nine CVADs inserted and fail: five tunnelled CVADs; three peripherally inserted central catheters (PICCs), and one non-tunnelled CVAD; with one tunnelled CVAD still *insitu*. The timeline and sequelae of each CVAD is described in Table 1. This equates to the child having a CVAD inserted every 100 days, each requiring a general anaesthetic and surgical procedure. Most complications resulting in CVAD failure were related to mechanical causes, most frequently dislodgement and fracture. In addition, over the last two years, the child's central vasculature has developed significant thrombotic occlusion, limiting future CVAD placements. Each failed CVAD restricted her parenteral nutrition, required the insertion of temporary peripheral intravenous devices, and/or necessitated antimicrobial therapy.

In 2015 the child developed a CVAD-associated bloodstream infection caused by *Klebsiella Pneumoniae*. This infection resulted in: a 22-day admission to a tertiary paediatric hospital; 14 days of intravenous (IV) antibiotics (Ceftriaxone) and three days of Gentamycin locks; hypokalemia (K^+ 2.7 mmol/L) requiring overnight potassium chloride infusion; CVAD fracture during hospital stay that was unable to be repaired resulting in CVAD removal; insertion of three peripheral IV catheters (one necessitating ultrasound guidance) until PICC insertion; and seven days of missed PN.

Table 1: Central vascular access device timeline

Date inserted	CVAD type inserted and site	Complications (not resulting in CVAD removal) during CVAD dwell	Date CVAD removed	Complication and reason for CVAD removal	Time period CVAD successful
18/06/2014	PICC; Left brachial	-	06/08/2014	Complete occlusion	49 days
07/08/2014	PICC; Right brachial	-	18/11/2014	Dislodged; tip no longer in central position	103 days
18/11/2014	Tunneled, cuffed CVAD; Left internal jugular	06/03/2015: Occluded right subclavian vein 07/03/2015: Tip position in right atrium, traversing tricuspid valve. Reposition required.	02/06/2015	CVAD blocked, right chest swelling. Internal catheter fracture, confirmed by contrast study	196 days
07/06/2015	Tunneled, cuffed CVAD; Right internal jugular	05/06/2015: Occluded true right subclavian vein; multiple collaterals formed 09/06/2015: Partial CVAD dislodgement (from SVC/RA junction to proximal SVC)	29/08/2015	Dislodged; tip no longer in central position.	83 days
29/08/2015	Tunneled, cuffed CVAD; Right internal jugular (re-wire)	-	14/10/2015	CVAD-associated bloodstream infection (*Klebsiella Pneumoniae*), and catheter fracture	46 days
25/10/2015	PICC;	-	26/03/2016	Dislodged; tip no	153 days

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	Right brachial			longer in central position. Unsuccessful PICC replacement.	
28/03/2016	Non-tunneled CVAD; Right internal jugular	-	30/03/2016	Elective replacement of an inappropriate device	2 days
30/03/2016	Tunneled, cuffed CVAD; Right internal jugular	-	03/04/2016	Catheter fracture; repair unsuccessful. Required prophylactic IV antibiotics, PIVC insertion, partial PN only.	4 days
04/04/2016	Tunneled, cuffed CVAD; Right internal jugular (re-wire)	06/06/2016: Catheter fracture; repaired successfully. Required prophylactic IV antibiotics, PIVC insertion, partial PN only.	06/10/2016	Catheter fracture; repair unsuccessful. Required prophylactic IV antibiotics, PIVC insertion, partial PN only.	185 days
07/10/2016	Tunneled, cuffed CVAD; Right internal jugular (re-wire)			Currently *insitu*	

CVAD=Central venous access device; IV= Intravenous; PICC= Peripherally inserted central catheter; PIVC= Peripheral intravenous catheter; PN= Parenteral nutrition

The local, institutional resources used when inserting each of these CVADs is substantial. An example of the immediate financial costs associated with inserting, or re-wiring, a tunnelled CVAD at the case study facility is described in Table 2. This does not include additional costs associated with treating, or attempting to treat, the underlying complication. A cost of $10,253 AUD (2016) per device is a major cost to paediatric hospitals; and the child has undergone six tunnelled CVAD insertion, or re-wiring, in her short life time.

Table 2: Local resources used to insert, or re-wire, a tunnelled CVAD in 2016 Australian Dollars (AUD)

Resources	Cost (AUD)
Staff [9, 10]	
Consultant pediatric surgeon ($199.16/hour): 2 hours	**398.32**
Training (Registrar, resident medical officer) pediatric surgeon ($128.98/hour): 2 hours	**257.55**
Registered Nurses or equivalent (operating specialty)($42.4711/hour): 2 nurses, 2 1/2 hours per nurse	**212.36**
Consultant anesthetist ($199.16/hour): 2 1/2 hours	**497.90**
Training (Registrar, resident medical officer) pediatric anesthetist ($128.98/hour): 2 ½ hours	**322.45**
Registered Nurse or equivalent (anesthetics and recovery specialty) ($42.4711 /hour): 3 hours	**127.42**
Location [11]	
Dedicated theatre suite (including equipment such as ultrasonography, imaging) ($80/minute): 1 ½ hours	**7,200.00**
Anesthetic recovery: at least 30 minutes	**89.98**
Hospital bed: at least 8 hours	**803.95**
Consumables [11, 12]	
Central venous access device and insertion equipment: frequently > 1 required	**275.00**
Sterile personal protective equipment ($5.00 each): 4 at least	**20.00**
Anesthetic medications (including inhaled, intravenous): multiple	**34.38**
Device dressing and security	**14.00**
TOTAL	**10,253.31**

DISCUSSION

The child's vascular access progression may seem unremarkable to paediatric clinicians, because such complications are common, and indepth data on repercussions are lacking. Yet, these experiences were extraordinarily negative for the child, her family and the healthcare system. Children with chronic health conditions requiring prolonged vascular access are common place.[13] The potentially preventable harm associated with their CVADs places a large burden on the healthcare system.

The costs and events described by the case study are in accordance with recent case-control studies demonstrating that paediatric CVAD-associated bloodstream infections cost healthcare systems around $55,646 (2011 USD) and 19 additional days in hospital,[14] with even higher costs ($69,332; 2011 USD; 21.2 additional days in hospital) for the haematology and oncology pediatric population.[15] Delays to treatment and the insertion of replacement CVADs due to other (non-infectious) types of CVAD failure and complication are also expensive for healthcare systems, and significantly reduce the quality of life, morbidity and mortality of paediatric patients.[16]

As demonstrated in the case study, the immediate interruption to necessary treatment results in an inability to receive prescribed fluids, nutrition, antibiotics and other necessary medicines. In addition to the immediate costs associated with the insertion of a replacement device, the insertion of new CVADs can result in serious complications such as pneumothorax and arterial puncture.[3, 17] Overall, the treatment of the complication, the interruption to necessary treatment, and complications associated with the new CVAD insertion are associated with an increased length of hospital stay, ICU stay and mortality.[18, 19] This case study has not explored the further financial and other costs borne by the patient and family such as lost time in paid employment, and opportunity costs in attendance at playgroup or family occasions.

It is timely for a new focus on long term vessel health and preservation in paediatrics. Children with CVADs are frequently managed by multiple medical and health professionals. 'Siloed' healthcare commonly sees decisions regarding device selection, placement and management made in isolation by individual clinicians from varying backgrounds (e.g. oncologist, surgeons, anaesthetists, nurse consultants). A paediatric vascular access continuity of care model, which has been advocated across many other areas of healthcare,[20, 21] has not been applied, and this is resulting in harm to the patients, their families and the healthcare institutions.

It is also time for high quality evidence to be generated to improve vascular access outcomes for paediatric patients. A recent focus on preventing harm associated with CVAD insertion and immediate infection has been highly successful in intensive care units,[7, 22, 23] however evidence is weaker on how to maintain CVAD performance during device dwell, and in chronic use settings. The child's case study, in agreement with previous literature,[2, 3] has demonstrated that the harm associated with CVADs frequently occurs during the later stages of CVAD dwell, not on the early days after insertion. Paediatric CVAD maintenance procedures such as flushing,[24] dressing,[25] administration set changes,[26] and hub decontamination[27] are not well supported by evidence, likely perpetuating these preventable complications for patients.

LEARNING POINTS/TAKE HOME MESSAGES

- Children with vascular access dependent chronic health conditions are at great risk for harm associated with vascular access complications.
- Paediatric central venous access device failure and complication rates are high, and have a substantial impact on the healthcare system, patient and family.
- High quality evidence to improve vascular access outcomes for paediatric patients is urgently needed.

REFERENCES

1. Australian Institute of Health and Welfare. Admitted patient care 2013-14: Australian hospital statistics. In: Australian Institute of Health and Welfare, editor. Canberra: Australian Government; 2015.
2. Ullman AJ, Cooke M, Kleidon T, Rickard CM. Road map for improvement: Point prevalence audit and survey of central venous access devices in paediatric acute care. Journal of paediatrics and child health. 2017;53(2):123-30.
3. Ullman AJ, Marsh N, Mihala G, Cooke M, Rickard C, M. Complications of central venous access devices: a systematic review. Pediatrics. 2015;136(5):e1331-44.
4. Modi BP, Jaksic T. Pediatric intestinal failure and vascular access. The Surgical clinics of North America. 2012;92(3):729-43, x.
5. World Health Organization. Preventing bloodstream infections from central line venous catheters 2012 [12/11/2012].
6. O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, O'Heard S, et al. Guidelines for the Prevention of Intravascular Catheter-Related Infections. Clin Infect Dis. 2011;52(9):e162-93.
7. Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med. 2006;355(26):2725-32.
8. Chopra V, Anand S, Hickner A, Buist M, Rogers MA, Saint S, et al. Risk of venous thromboembolism associated with peripherally inserted central catheters: a systematic review and meta-analysis. Lancet. 2013;382(9889):311-25.
9. Queensland Health and Department of Education and Training. Nurses and Midwives Certified Agreement (EB9) In: Training QHaDoEa, editor. Queensland: Queensland Government; 2016.
10. Queensland Health and Department of Education and Training. Medical Officers' (Queensland Health) Certified Agreement (No.4). In: Queensland Health and Department of Education and Training, editor. Brisbane: Queensland Government; 2015.
11. Health Q. Queensland Health Tender costings. In: Health Q, editor. Brisbane, Australia: Queensland Government; 2016.
12. Rickard CM, Edwards M, Spooner AJ, Mihala G, Marsh N, Best J, et al. A 4-arm randomized controlled pilot trial of innovative solutions for jugular central venous access device securement in 221 cardiac surgical patients. Journal of Critical Care. 2016;36:35-42.
13. Barczykowska E, Szwed-Kolinska M, Wrobel-Bania A, Slusarz R. The use of central venous lines in the treatment of chronically ill children. Advances in clinical and experimental medicine : official organ Wroclaw Medical University. 2014;23(6):1001-9.
14. Goudie A, Dynan L, Brady PW, Rettiganti M. Attributable cost and length of stay for central line-associated bloodstream infections. Pediatrics. 2014;133(6):e1525-32.
15. Wilson MZ, Rafferty C, Deeter D, Comito MA, Hollenbeak CS. Attributable costs of central line-associated bloodstream infections in a pediatric hematology/oncology population. Am J Infect Control. 2014;42(11):1157-60.
16. van Miert C, Hill R, Jones L. Interventions for restoring patency of occluded central venous catheter lumens. Cochrane Database Syst Rev. 2012;4:Cd007119.
17. Rey C, Alvarez F, De La Rua V, Medina A, Concha A, Diaz JJ, et al. Mechanical complications during central venous cannulations in pediatric patients. Intensive Care Med. 2009;35(8):1438-43.
18. Schwebel C, Lucet JC, Vesin A, Arrault X, Calvino-Gunther S, Bouadma L, et al. Economic evaluation of chlorhexidine-impregnated sponges for preventing catheter-related infections in critically ill adults in the dressing study. Crit Care Med. 2012;40(1):11-7.
19. Soufir L, Timsit JF, Mahe C, Carlet J, Regnier B, Chevret S. Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk-adjusted, cohort study. Infect Control Hosp Epidemiol. 1999;20(6):396-401.
20. Chopra V, Flanders SA, Saint S, Woller SC, O'Grady NP, Safdar N, et al. The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results From a Multispecialty Panel Using the

RAND/UCLA Appropriateness Method. Ann Intern Med. 2015;163(6 Suppl):S1-S40.
21. Moureau NL, Trick N, Nifong T, Perry C, Kelley C, Carrico R, et al. Vessel health and preservation (Part 1): a new evidence-based approach to vascular access selection & management. J Vasc Access. 2012;13(3):351-6.
22. Lau CS, Chamberlain RS. Ultrasound-guided central venous catheter placement increases success rates in pediatric patients: a meta-analysis. Pediatric research. 2016.
23. Gilbert RE, Mok Q, Dwan K, Harron K, Moitt T, Millar M, et al. Impregnated central venous catheters for prevention of bloodstream infection in children (the CATCH trial): a randomised controlled trial. Lancet. 2016;387(10029):1732-42.
24. Bradford NK, Edwards RM, Chan RJ. Heparin versus 0.9% sodium chloride intermittent flushing for the prevention of occlusion in long term central venous catheters in infants and children. Cochrane Database Syst Rev. 2015;11:Cd010996.
25. Ullman AJ, Cooke ML, Mitchell M, Lin F, New K, Long DA, et al. Dressings and securement devices for central venous catheters (CVC). Cochrane Database Syst Rev. 2015;9:Cd010367.
26. Ullman AJ, Cooke ML, Gillies D, Marsh NM, Daud A, McGrail MR, et al. Optimal timing for intravascular administration set replacement. Cochrane Database Syst Rev. 2013;9:CD003588.
27. Moureau NL, Flynn J. Disinfection of Needleless Connector Hubs: Clinical Evidence Systematic Review. Nursing research and practice. 2015;2015:796762.

FIGURE/VIDEO CAPTIONS

N/A

PATIENT'S PERSPECTIVE

N/A

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