Cardiology in the Young

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Use of temporary tracheostomy occlusion to reduce the risk of sternal wound infection after sternotomy in congenital cardiac surgery

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Abstract

Objective: To describe a method of reducing the risk of sternal wound infection after sternotomy in children with a pre-existing tracheostomy. To report our outcomes using this method from 1 January, 2013 to 31 August, 2023. *Methods:* We describe a method for temporarily occluding the tracheal stoma with a removable implant with the primary goal of reducing the risk of sternotomy wound infection by preventing soilage due to tracheostomal secretions. We then performed a retrospective review of all children who underwent temporary tracheostomal occlusion between 1 January, 2013 and 31 August, 2023 at our quaternary care children's hospital. Clinical variables were extracted from the hospital medical records. The rates of antibiotic use and minor and major complications during the period when the stoma plug was in place were recorded. *Results:* Totally, 19 patients underwent tracheal stoma plugging prior to sternotomy and were included in our analysis. There were two cases of sternal wound infection; one case occurred while the stoma plug was in place, and one developed four days following plug removal. There was one minor complication, with one patient requiring stoma revision via serial dilation at bedside at the time of recannulation. There were no deaths. *Conclusion:* Temporary occlusion of the tracheal stoma with an impermeable plug is a viable option for reducing the risk of sternal wound infection in children with a pre-existing tracheostomy who are undergoing sternotomy.

Children with congenital cardiac disease frequently have numerous comorbidities, including respiratory or pulmonary ailments requiring a tracheostomy. This requirement typically stems from associated congenital airway anomalies, broncho- or tracheomalacia, or chronic respiratory failure. The presence of a tracheostomy in patients with a fresh sternal wound is a risk factor for sternal wound infection or mediastinitis, likely owing to direct soiling of the sternal wound by secretions from the tracheostoma.[1,2] Patients in whom a tracheostomy is placed immediately after sternotomy have high rates of deep sternal wound infection, and delaying tracheostomy placement by just days significantly reduces this incidence.[3] It is thus challenging to prevent sternal wound infection in patients undergoing sternotomy with a pre-existing tracheostomy. In the paediatric population, approximately 10% of patients who undergo tracheostomy and cardiac surgery in the same admission have a tracheostomy placed before cardiac surgery.[4] Few tools are available to surgeons wishing to reduce the risk of sternal wound infection in patients with a tracheostomy who require a sternotomy. Published reports of cardiac surgery performed in these patients have primarily focused on alternate surgical incisions for the sternotomy, or on non-sternotomy approaches to the mediastinum.[5–7] However, these approaches are often not feasible in children, where the already small operative field cannot be reduced further. In this manuscript, we describe a technique for temporarily occluding the tracheostoma to both protect the sternal wound during healing and maintain the patency of tracheostomy stoma for future recannulation. This method relies on temporary intubation of the patient during the period of tracheostomy occlusion. The method was developed by Dr Rutter and associates at Cincinnati Children's Hospital, and we have used this method for 10 years at the Stanford Children's Health Lucile Packard Children's Hospital. We report our 10-year outcomes in this publication.

Materials and methods

Patients and setting

From 1 January, 2013 to 31 August, 2022, 21 children underwent tracheal stoma occlusion at Lucile Packard Children's Hospital of Stanford University, a quaternary care referral centre. The medical records of these 21 patients were retrospectively reviewed, and patients who did not undergo sternotomy were excluded. The institutional review board of Stanford University School of Medicine approved this study (IRB #47365).

Tracheal stoma occlusion protocol

Tracheal stoma occlusion is performed by a paediatric otolaryngologist in the operating room on the day of the planned sternotomy. First, a formal airway evaluation by means of microdirect laryngoscopy and bronchoscopy using a Hopkins rod endoscope is performed, and the patient is intubated by the otolaryngologist. This is followed by decannulation of the tracheostomy and positioning of the cuff of the endotracheal tube between the tracheostoma and the carina. The stoma plug is then created by rolling a single strip of Xeroform (Bismuth-treated) gauze into a plug with dimensions comparable to the tracheal stoma's diameter and depth. A black 2-0 silk suture is then passed through and tied around the plug to maintain the dimensions of the plug (Fig. 1a). That suture is intentionally kept long and taped to the patient's neck so that the plug can be easily removed in the case of an airway emergency. The plug is then inserted into the stoma and secured with a blue 4-0 prolene suture placed through the plug and around the periphery of the stoma in a purse-string fashion (Fig. 1b). Care is exercised to secure the plug such that it spans the entire depth of the stoma, but does not risk falling into the airway if the endotracheal tube is inadvertently withdrawn above the stoma. An adherent dressing is placed over the plug, taking care to cover all of the wound edges. The sternotomy incision is then kept at least 1 cm below the stoma to prevent inadvertent connection. The adherent dressing can be changed as-needed during the recovery period. The cardiac surgery and ICU teams are informed that in the case of an emergency requiring recannulation of the tracheostomy, the blue suture should be cut and the black suture should then be used to remove the plug from the stoma to access the airway. Appropriate signage is displayed at the patient's bedside, along with standard airway management instructions and tracheostomy equipment.

Although the primary goal of the above procedure is to avoid soiling of the sternotomy wound with tracheal secretions, a secondary goal is to maintain tracheal stoma patency and avoid tracheal stoma revision at the time of stoma recannulation with the tracheostomy tube. Thus, the surgeon must ensure that a large enough stoma plug is placed through the length of the tracheal stoma to prevent contracture of the wound. Readers should note that the occlusion is not intended to be airtight; the endotracheal tube cuff must be kept inflated below the stoma to prevent air leakage under the stomal dressing.

After the procedure, the patient is evaluated daily by the otolaryngology team to ensure that the plug is still in place and secure. The adherent dressings are changed as needed to prevent soiling and leak. Removal of the stoma plug is performed at a time chosen by the cardiac surgery team based upon a daily assessment of the sternotomy wound's healing. The plug is removed at bedside in the ICU by the otolaryngologist. The blue purse string suture is cut, and the black suture is pulled to remove the plug. The endotracheal tube is then withdrawn to the just above the tracheal stoma, and the tracheostomy tube is replaced in the stoma. After confirming successful recannulation, the endotracheal tube is completely removed.

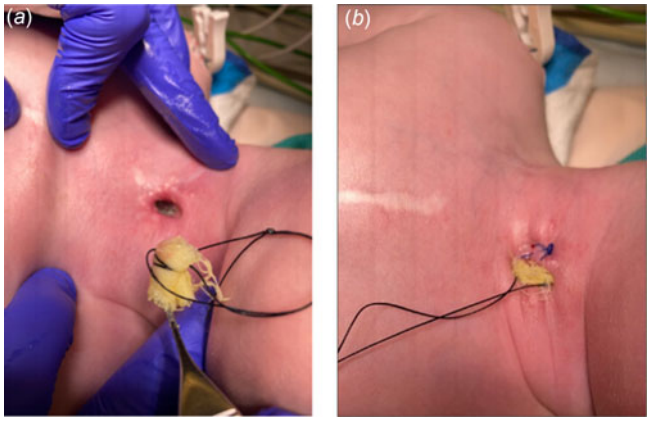

Figure 1. Temporary tracheostomy occlusion with a xeroform plug. ***a***) After the patient is intubated nasally or orally and the tracheostomy tube is removed, a compact plug is formed from a single piece of xeroform gauze. Black 2.0 or 3.0 silk suture is tied through and around the plug to keep it compact. A long tail of suture is left as a handle in case the plug needs to be rapidly removed. ***b***) The plug is inserted into the stoma and secured with a purse-stringed blue prolene suture. The plug is then dressed with an adherent dressing (not shown).

The success of the tracheal stoma plugging procedure depends in large part on communication and collaboration between the otolaryngology, cardiothoracic surgery, and ICU teams. The otolaryngology team performs the procedure, informs all other teams of the contingency airway plans, and monitors the plug at least daily as above. The cardiothoracic surgery team is responsible for assessing the sternotomy and its state of healing, and informing the other teams as soon as the wound is felt to be healed enough to replace the tracheostomy. The ICU team notifies all other teams of any possible early infectious symptoms and manages the day-to-day patient needs. If the neck wound is soiled or the dressing saturated, it is changed with assistance from the otolaryngology team.

The categorisation of cardiac surgical site infection into superficial, deep, or organ/space aligns with the criteria provided by the National Healthcare Safety Network. Superficial surgical site infection pertains solely to the involvement of skin and subcutaneous tissue around the incision site. Deep surgical site infection encompasses deeper layers, including fascia and muscle, and may exhibit local signs such as an abscess or systemic symptoms. Organ/space surgical site infection, such as mediastinitis, signifies a more extensive infection that reaches deeper structures, like the sternal bone[5].

Data collection

For each patient in the study, we recorded the date of birth, the date and indication for tracheostomy, the date and indication for sternotomy, whether sternal closure was delayed, whether a wound vacuum was placed over the incision, the date of placement of the stoma plug, and the date of removal of the stoma plug and recannulation with the tracheostomy tube. We also recorded the use of antibiotics during the period when the stoma plug was in place, as well as the following complications: accidental aspiration of stoma plug, need for stoma revision, need to exchange the stoma plug for a new one, and incidence of sternal wound infection

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during or after plug placement. Data were compiled into a table, and Matlab (R2022b, The Mathworks) was used to calculate the age at tracheostomy, sternotomy, and stoma plug placement, the stoma maturity at stoma plug placement, and the duration of stoma plug use. Plots and statistical analyses were performed using Matlab.

Lucile Packard Children's Hospital conducts surgical site infection surveillance per guidelines outlined by the Centers for Disease Control and Prevention's. The surveillance system gathers data on all types of cardiac surgery SSIs, including superficial incisional, deep incisional, organ/space, and SSIs attributed to specific event types.[5] This data collection spans from 1 January, 2013 to 22 December, 2022, with a 90-day monitoring period following cardiac surgery procedures. The total count of cardiac surgeries performed within this timeframe is captured through a report that extracts operative procedure codes and Current Procedural Terminology from electronic medical records.

Results

Totally, 21 patients underwent tracheal stoma occlusion between 1 January, 2013 and 31 August, 2023. Of these, 19 had cardiac surgery requiring a sternotomy and were included in this study. Two patients were excluded: one received stoma occlusion prior to a laparotomy and the other prior to cannulation for extracorporeal membrane oxygenation.

The patients in our study received a tracheostomy at ages ranging from 19 days old to 16 years old (mean 2.2 years, median 0.4 years, Table 1, Fig. 2a). The stoma plugs were placed in mature tracheal stomas, with the average maturity of a stoma being 767 days old (range 38 days–16 years old, Table 1, Fig. 2b). On average, the stoma was kept occluded for 10 days, with a median placement duration of 6 days (range 2–45 days, Fig. 2c). The single patient with an occlusion duration of 45 days was an outlier; the occlusion was maintained due to poor healing of her sternal wound. There were no deaths during the study period.

All patients received antibiotics on the day of the operation and post-operative day 1 at least. In addition, all but two of the patients in our study received at least one broad-spectrum antibiotic during the time their tracheal stoma was occluded (Table 2). The choice and duration of antibiotic treatment was guided by the cardiothoracic surgery, ICU, and infectious disease teams. Five patients had delayed sternal closure, with a mean delay until closure of 7.4 days in these patients (range 7–10 days). Three patients had an incisional wound vacuum placed after chest closure.

There were no instances of accidental aspiration of the tracheal stoma plug in our study. One patient required simple stoma revision prior to reinsertion of their tracheostomy. The plug of patient number 12 was found to be displaced on the day of recannulation, which resulted in a stenotic tracheal stoma. This required uncomplicated blunt dilation at the bedside prior to recannulation.

Two patients developed sternal wound infections during or after stoma plug placement. Patient number 1 developed a sternal wound infection with *Acinetobacter baumanii*, requiring mediastinal irrigationon post-operative day 8. This patient had undergone delayed chest closure due to worsening lung reperfusion injury requiring extracorporeal membranous oxygenation support. On gross examination, the infection appeared limited to the superficial layers of the sternal wound, with deeper mediastinal tissues demonstrating no evidence of purulence or infection. This was thought to be due to seeding from a poorly sealed tracheostomy, as previous tracheal cultures had grown *Acinetobacter baumanii*. The patient was placed on cefepime, and repeat mediastinal irrigationon post-operative day 10 showed significant improvement, so the chest was closed on this day. The patient was treated with 6 weeks of cefepime and eventually discharged home. Of note, this was a revision sternotomy, and this patient had a previous episode of mediastinitis at a referringhospital prior to her revision sternotomy, though the pathogen was unknown. The second patient who developed sternal wound infection was patient number 13. The patient became tachypnoeic and febrile four days after stoma plug removal and tracheostomy tube replacement. Tracheal cultures on that day grew *Serratia marcescens*, and sternal wound cultures two days later confirmed *S. marcescens* infection of the chest as well. A wound vacuum was placed and the patient received 8 days of intravenous cefepime, followed by 4 weeks of outpatient oral levofloxacin on discharge. Patient number 1 had a stoma maturity of 258 days at the time of occlusion and underwent temporary stoma occlusion for 16 days. Patient number 13 had a stoma maturity of 330 days and underwent stoma occlusion for 2 days.

There were 3318 cardiac surgeries performed at Lucile Packard Children's Hospital during the study period. Of these, 57 (1.7%) developed superficial surgical site infections, 16 (0.5%) developed deep surgical site infections, and 19 (0.6%) developed mediastinitis.

Discussion

The presence of a tracheostomy at the time of sternotomy significantly increases the risks of mediastinal wound infection.[1,6–9] This is especially true in the paediatric population, where the sternotomy cannot be reduced in size to mitigate the risk of contamination of the sternal wound by the tracheostomy. Apart from reduction of sternotomy size, the only other procedure described in the literature involves covering the sternal wound with a sterile drape to protect it from tracheostomy secretions.[10] This approach would likely limit physical access to the patient and be difficult to implement in the paediatric population. In the case of unstable patients in whom the chest is left open during the initial postoperative period, this approach is not practical. Our data show that measures can be taken to mitigate the risk of infection in children with tracheostomies undergoing sternotomy, including temporary occlusion of the stoma, empiric antibiotics, and careful decision-making regarding timing of tracheostomy replacement

In our series, the tracheal stoma plug was used for up to 45 days to protect the sternal wound and maintain stoma patency. Our low rate of mechanical complications, with no accidental aspirations of the plug, and only one patient necessitating a stoma revision, indicates that our method of securing the plug with a purse-stringed suture is secure and adequate.

We are unable to determine whether the rate of sternal wound infection in our cohort was lower than it would have been in a group with patent tracheal stomas due to our lack of a control group. Because of the documented risk of leaving a tracheostomy in place in the presence of a fresh sternotomy, there was not equipoise to design a control group using patients with a patent tracheostomy stoma at the time of surgery. Temporary stomal occlusion is part of an approach of multiple interventions we employ to try and reduce risk of sternal infection and mediastinitis. Comparison of our cohort to the group of all patients undergoing cardiac surgery at our hospital reveals an infection rate of 10.5% (tracheostomy cohort) as compared to 2.7% (all cardiac surgeries), highlighting the increased risk conferred by the presence of tracheostomy.

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Table 1. Demographic data describing the patient cohort

Patient	Age at tracheostomy placement (years)	Age at tracheostomy occlusion (years)	Stoma maturity (days)	Plug duration (days)	Tracheostomy indication	Primary or revision sternotomy
1	1.42	2.13	258	16	Tracheolaryngomalacia	Revision
2	0.05	0.33	102	7	Respiratory Failure	Revision
3	0.66	0.87	78	12	Respiratory failure	Revision
4	0.56	7.57	2562	6	Chronic respiratory failure	Revision
5	0.25	1.39	415	2	Central hypoventilation syndrome	Primary
6	16.8	16.99	68	5	Acute hypoxic failure, unknown	Primary
7	0.22	1.36	415	14	Chronic respiratory failure	Primary
8	0.24	0.41	61	5	Respiratory failure	Primary
9	0.35	7.89	2754	5	Chronic respiratory failure	Primary
10	0.42	0.59	62	4	Respiratory failure	Revision
11	0.28	1.8	556	6	Bronchomalacia	Revision
12	0.16	0.67	185	14	Tracheomalacia, bronchomalacia	Revision
13	0.34	1.24	330	2	Respiratory failure	Revision
14	15.75	16.04	107	4	Respiratory failure	Revision
15	1.04	1.68	235	12	Respiratory failure	Revision
16	0.11	0.35	85	25	Tracheobronchomalacia	Primary
17	1.42	18.4	6200	6	Chronic respiratory Failure	Revision
18	0.36	0.55	70	2	Respiratory failure	Revision
19	1.6	1.71	38	45	Respiratory failure	Primary

Table 2. Experiences of the patient cohort with regards to antibiotic exposure and outcomes of the tracheal stoma plug

Patient	Antibiotics	Accidental aspiration	Stoma revision	Sternal infection
1	Cefazolin, meropenem, vancomycin, cefepime	0	0	1
2	Cefazolin, meropenem	0	0	0
3	Cefazolin, piperacillin-tazobactam	0	0	0
4	Cefepime, vancomycin	0	0	0
5	Cefazolin, cefepime, vancomycin, piperacillin-tazobactam	0	0	0
6	Amphotericin, ganciclovir, vancomycin, ceftaroline, meropenem	0	0	0
7	Cefepime, meropenem	0	0	0
8	Ampicillin-sulbactam	0	0	0
9	Cefazolin, levofloxacin, cefepime	0	0	0
10	Vancomycin, cefepime	0	0	0
11	Cefazolin, cefepime	0	0	0
12	Cefazolin	0	1	0
13	Cefazolin	0	0	1
14	Cefazolin, cefepime, caspofungin	0	1	0
15	Vancomycin, piperacillin-tazobactam, gentamicin, meropenem, fluconazole, cefepime, caspofungin	0	0	0
16	Vancomycin, meropenem	0	0	0
17	Vancomycin, cefazolin	0	0	0
18	Cefepime	0	0	0
19	Meropenem	0	0	0

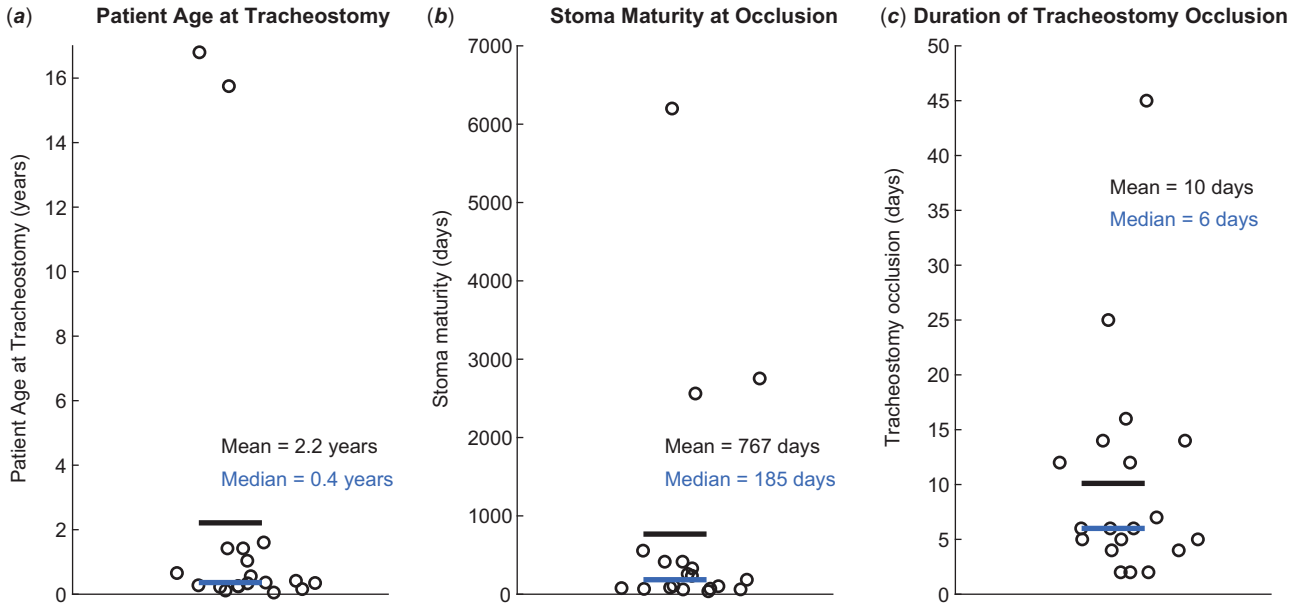

Figure 2. Maturity of stoma and duration of stoma occlusion. ***a***) The age of the patient at the time of tracheostomy is plotted in years for each patient. The age at tracheostomy placement ranged from 19 days to 16.8 years old (mean 2.2 years, median 0.4 years). ***b***) Temporary tracheostomy occlusion was performed on tracheal stomas whose maturity ranged from 38 days to 16 years (mean 767 days, median 185 days). ***c***) The duration of tracheostomy occlusion ranged from 2 to 45 days (mean 10 days, median 6 days).

However, our results compare favourably to the limited data available in the literature regarding patients with tracheostomy. In one report of 14 paediatric single-ventricle patients who underwent 22 sternotomies with a tracheostomy in place, 3 patients developed mediastinitis.[6] Another report cites two mediastinal infections in a cohort of 19 patients who had 26 sternotomies.[2]

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One limitation of our stoma plugging procedure is the associated need to keep the patient intubated until the sternal wound is adequately healed. Prolonged intubation places patients at risk for intubation-related complications such as laryngeal trauma, increased sedation requirements, pneumonia, and limits their physical mobility. However, given the high morbidity of sternal wound infections, we feel that the above risks outweigh the benefit of a likely reduced incidence of sternal wound infections. In addition, maintaining the patency of the stomal tract allows prompt recannulation once the sternotomy is adequately healed, rather than requiring additional operative intervention to replace the tracheostomy, which might prolong duration of intubation. In our series, we did not experience any intubation-related complications in patients undergoing tracheal occlusion.

The tracheostomy occlusion procedure described here requires a strong cooperative relationship between the otolaryngology, cardiothoracic surgery, and ICU teams. In our practice, each of these teams has clearly delineated responsibilities, see the patients daily, and communicate on a daily basis regarding the plan for removal of the stoma plug and replacement of the tracheostomy tube.

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Competing interests. None.

Ethical standards. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national guidelines on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the institutional committees.

References

1. Force SD, Miller DL, Petersen R, et al. Incidence of deep sternal wound infections after tracheostomy in cardiac surgery patients. Ann Thorac Surg 2005; 80: 618–622.
2. Ortmann LA, Manimtim WM, Lachica CI. Outcomes of tracheostomy in children requiring surgery for congenital heart disease. Pediatr Cardiol 2017; 38: 296–301.
3. Pilarczyk K, Marggraf G, Dudasova M, et al. Tracheostomy after cardiac surgery with median sternotomy and risk of deep sternal wound infections: is it a matter of timing? J Cardiothorac Vasc Anesth 2015; 29: 1573–1581.
4. Maxwell BG, McMillan KN. Tracheostomy in children with congenital heart disease: a national analysis of the kids' inpatient database. PeerJ 2014; 2: e568.
5. CDC. National and State Healthcare-Associated Infections Progress Report, 2023. https://www.cdc.gov/hai/data/portal/progress-report.html.
6. Cotts T, Hirsch J, Thorne M, Gajarski R. Tracheostomy after pediatric cardiac surgery: frequency, indications, and outcomes. J Thorac Cardiovasc Surg 2011; 141: 413–418.
7. Kaneda T, Saga T, Kitayama H, et al. [Application of the lower partial sternotomy approach to patients who may need tracheostomy in the early period after cardiac surgery]. Kyobu Geka 2011; 64: 387–9.
8. Freeland KT, Davies JE. Off-pump CABG in a patient with laryngectomy and permanent tracheostomy utilizing low midline skin incision with transverse skin flaps and manubrium sparing sternotomy. J Card Surg 2016; 31: 439–440.
9. Kasai M, Osako M, Yamada T, Yamabe K. Off-pump coronary artery bypass grafting in a tracheostomy patient. Gen Thorac Cardiovasc Surg 2019; 67: 803–805.
10. Kimura S, Kurisu K, Tanaka K, Kumeda H, Tominaga R. Coronary artery bypass grafting and aortic valve replacement in a patient with a tracheostoma. Ann Thorac Cardiovasc Surg Off J Assoc Thorac Cardiovasc Surg Asia 2004; 10: 311–313.

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