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Infections and outcomes after cardiac surgery—The impact of outbreaks traced to transesophageal echocardiography probes

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Background: Infections are a frequent complication of cardiac surgery. The intraoperative use of transesophageal echocardiography (TEE) may be an underrecognized risk factor for post-operative infections. The aim of this study was to investigate infection rates and outcomes after cardiac surgery in a nationwide cohort, especially in relation to periods where surface damaged TEE probes were used.

Methods: This was a retrospective, observational study at Landspitali University Hospital. All consecutive cardiac surgery patients from 1 January 2013 to 31 December 2017 were included. Patients' charts were reviewed for evidence of infection, post-operative complications or death.

Results: During the study period, 973 patients underwent cardiac surgery at Landspitali and 198 (20.3%) developed a post-operative infection. The most common infections were: Pneumonia (9.1%), superficial surgical site (5.7%), bloodstream (2.8%) and deep sternal wound (1.7%). Risk factors for developing an infection included: The duration of procedure, age, insulin-dependent diabetes, EuroScore II, reoperation for bleeding and an operation in a period with a surface damaged TEE probe in use. Twenty-two patients were infected with a multidrug resistant strain of *Klebsiella oxytoca*, 10 patients with *Pseudomonas aeruginosa* and two patients developed endocarditis with *Enterococcus faecalis*. All three pathogens were cultured from the TEE probe in use at respective time, after decontamination. The 30-day mortality rate in the patient cohort was 3.2%.

Conclusions: The intraoperative use of surface damaged TEE probes caused two serious infection outbreaks in patients after cardiac surgery. TEE probes need careful visual inspection during decontamination and probe sheaths are recommended.

1 | INTRODUCTION

Infections are among the most frequent complications after cardiac surgery[1,2] and have consistently been linked to longer duration of stay and increased mortality.[3-5] Recent reports have shown rates of surgical site infections from 4.9% to 8.1%,[6,7] urinary tract infections from 0.7% to 6%,[6,8-10] blood stream infections from 1.1% to 2.3%,[3,8,10,11] and deep sternal wound infections from 0.6% to 1.6%.[3,9,10]

Post-operative pneumonia, in particular, has been the subject of numerous studies, reporting variable incidence rates, from 2.4% to 10.7%.[3,6,9,13,14] Many risk factors for developing pneumonia post-operatively have been identified and include: age,[9,13,14,18] chronic pulmonary disease,[3,9,13,14] heart failure,[3,9] female gender,[5,9,19] duration of surgery[3] and cardiopulmonary bypass,[14] duration of mechanical ventilation,[3,13,18,19] re-intubation,[17,18,20] transfusion of blood products[14,17,18] and emergency surgery.[4] Most of these factors are not amenable to modification.

A less well-known potential causative factor in the development of pneumonia after cardiac surgery is the use of transesophageal echocardiography (TEE) probes, which are used in the majority of all cardiac procedures.[21] A few outbreaks have been described linking TEE probes with respiratory infections after cardiac surgery, *Enterobacter cloacae*[22] (17 patients) and *Pseudomonas aeruginosa*[23] (eight patients) in Japan and *Escherichia coli*[24] (eight patients) in the United States. A common factor in all three outbreaks was damage to the probes, presumably preventing adequate decontamination.

1.1 | The outbreaks

In the year 2014, multiple patients in the intensive care unit (ICU) at Landspitali University Hospital developed pneumonia with an extensively beta-lactam resistant *Klebsiella oxytoca*. After a detailed investigation for possible sources of contamination in the ICU environment, the same strain of *K oxytoca* was isolated from a TEE probe which had been used in most cardiac operations at the hospital. Careful inspection under magnification revealed a small crack at the junction of the tip and the shaft of the TEE probe. The probe was subsequently replaced with another one that was previously unused but several years old. The use of a protective sheath to cover the probe while in patient use was encouraged, but not enforced. The outbreak strain of *K oxytoca* was not identified in any cardiac patient after changing the TEE probe. However, in the year 2017, three patients died of septic shock due to *P aeruginosa* shortly after cardiac surgery and two patients developed endocarditis due to *Enterococcus faecalis* between 1 and 12 weeks after cardiac surgery. One of those patients died. Inspection of the replacement TEE probe revealed minute damage, see Figure 1, and both pathogens were cultured from the probe despite decontamination.

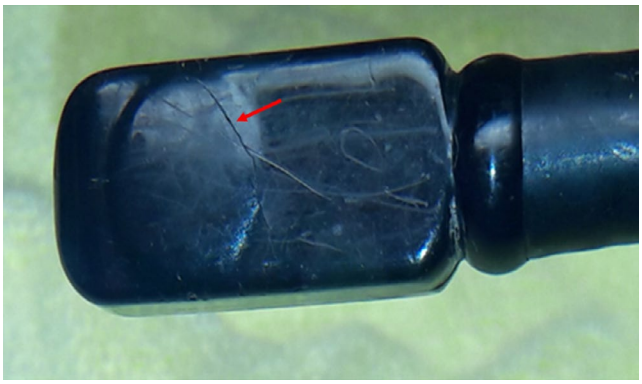

FIGURE 1 The tip of one of the transesophageal echocardiography probes in use during the study period. With magnification and specific lighting used in this photograph, numerous superficial scratches and a crack (arrow) in the plastic casing can be visualized. The damage was not obvious to the naked eye. The outbreak strains of *Pseudomonas aeruginosa* and *Enterococcus faecalis* were isolated from this crack, after the probe had been decontaminated and was ready for use (Photo: Thorkell Thorkelsson) [Colour figure can be viewed at wileyonlinelibrary.com]

Editorial comment

This report describes an analysis of post-operative infectious complications during a recent period in a single centre cardiac surgical cohort. There is specific focus on risk associated with reused equipment, with tracking to transesophageal echo probes.

Given the two recent outbreaks described above, the aim of our study was to examine the incidence of infections after cardiac surgery in a nationwide population and how it related to periods with a contaminated TEE probe in use. Additionally, we describe the risk factors for infections and the general outcome of cardiac surgery patients in Iceland.

2 | METHODS

2.1 | Study design and setting

This was a retrospective, nationwide, observational study conducted at Landspitali University Hospital in Reykjavik, Iceland. Landspitali is a tertiary care centre serving a population of 350 000 with around 200 open-heart surgeries performed each year. It is the sole provider of cardiac surgery in Iceland. During the study period, a single TEE probe was located in the cardiac surgery theatre and used in the majority of procedures. A second probe could be obtained if needed from the ICU (eg, in case of two concurrent operations). Post-operative cardiac surgery patients were admitted to a 7 bed multidisciplinary ICU for at least one night. Per protocol cefazolin was used for surgical antibiotic prophylaxis (1 g every 8 hours for 48 hours) or clindamycin in patients allergic to beta-lactam antibiotics. Microbiology cultures were only requested in cardiac surgery patients upon clinical suspicion of infection.

2.2 | Patient selection and data collection

All consecutive patients (≥18 years) who underwent open-heart surgery at Landspitali from 1 January 2013 to 31 December 2017 were included. Data collected from patients´ electronic medical charts, hospital laboratories and the operation planning system were entered into an Excel spreadsheet (Microsoft Office 2016, Version 1810). The European System for Cardiac Operative Risk Evaluation (EuroScore II) scoring system was used to assess preoperative and surgical risk factors.[25] The occurrence or absence of infection in each patient was judged by study authors using all available clinical data. Infections were defined and classified based on the definitions of the European Center for Disease Prevention and Control.[26]

Microbiology cultures were reviewed in all patients for 30 days after surgery, or up to 90 days for deep surgical infections and endocarditis. Additional outcome data collected included the development of a new-onset atrial fibrillation, stroke, need for

pleurocentesis, pericardiocentesis, renal replacement therapy, circulatory mechanical assist devices or reoperation, length of ventilation, need for re-intubation, length of stay in the ICU and hospital, and 30-day and in-hospital mortality. Two periods with a damaged and contaminated TEE probe in use were defined: From the date of surgery of the first (30 October 2013) and the last (12 November 2014) patient with *K oxytoca* pneumonia and the first (15 September 2016) and last (12 April 2017) patient with *P aeruginosa* pneumonia.

2.3 | End points

The main end point was the diagnosis of a new infection within 30 days after cardiac surgery, or 90 days for deep surgical site infections and endocarditis. Secondary end points included the incidence of complications as described above and mortality after cardiac surgery.

2.4 | Statistical analysis

Statistical analysis was performed using SPSS (IBM, Build 1.0.0.1126). Proportions are presented as percentage with confidence intervals. For normally distributed data, means and standard deviation (SD) are reported. The median and interquartile range (IQR) are reported for non-normally distributed data. Pearson's chi-squared test was used for categorical variables and odds ratios (OR) are reported with 95% confidence intervals (CI). Mann-Whitney *U* test was used for comparing length of stay between groups. For analysis of risk factors for infections and mortality, patient characteristics were entered into a univariate logistic regression with development of an infection or mortality as the dependent variable. Factors associated individually with the development of an infection ($P < 0.05$) were entered into a forward conditional multivariate logistic model. Missing values were common for preoperative pulmonary artery pressure (67% of subjects), preoperative left ventricular ejection fraction (11% of subjects) and ventilation time (17% of subjects) but otherwise missing data were <1%. When calculating the EuroScore II, missing data were presumed to have been normal.

3 | RESULTS

3.1 | The patient cohort

Nine hundred seventy-three patients underwent open-heart surgery at Landspitali in the 5-year study period (2013-2017), with the annual number of operations decreasing from 224 in the first year to 141 in the last year of the study. Patient characteristics are presented in Table 1.

3.2 | Post-operative infections

One hundred ninety-eight (20.3%) patients developed one or more infection post-operatively, see Table 2. The total number of registered infections was 273.

Pneumonia was the most common infection and was diagnosed in 89 patients (9.1%). The incidence rate was 13.8% (95% CI 10.5%-17.8%) in the two periods with a damaged TEE probe in use and 6.6% (95% CI 5.0%-8.9%) in other periods. A marked drop in pneumonia incidence was observed after TEE probe changes, see Figure 2.

Of all 89 patients with pneumonia, 67 (74.1%) were diagnosed while still in the ICU. The median time of diagnosis was on post-operative day 3 (IQR 2-4). The majority of patients with pneumonia (61 [68.5%]) had positive microbiological cultures, these came from tracheal aspirates (42), bronchoalveolar lavage (11) and sputum (8). The most commonly isolated pathogens were: *K oxytoca* (23), *P aeruginosa* (10), *Serratia marcescens* (8), *E cloacae* (8), *Klebsiella pneumoniae* (7) and *E coli* (5). Incidence rates for *E cloacae*, *K pneumoniae* and *E coli* were low throughout the study period but *K oxytoca* and *P aeruginosa* exhibited peaks in incidence, see Figure 3.

3.3 | Two outbreaks traced to damaged transesophageal echocardiography probes

An extensively beta-lactam resistant strain of *K oxytoca* was found in respiratory samples of 22 patients after intraoperative use of the first contaminated TEE probe. One patient died during the hospital stay but the death was not considered to be related to the infection. With the second probe, a total of 10 patients had *P aeruginosa* in respiratory samples, of which three also had a bloodstream infection. All three presented with septic shock within 3 days of their surgery and died in hospital. One additional patient with *P aeruginosa* pneumonia died before hospital discharge. Also with the second probe, two patients developed endocarditis with *E faecalis* in a biologic valve prosthesis within a 3-month period, one of whom died. All three bacteria (*K oxytoca*, *P aeruginosa* and *E faecalis*) could be cultured from the TEE probe in use at the respective time (after decontamination).

3.4 | Risk factors for and the impact of infections

Several factors were associated with the development of a post-operative infection, see Table 3.

In a multivariate model, the duration of procedure (adjusted OR 1.006, 95% CI 1.004-1.008, $P < 0.001$), age (adj. OR 1.035, 95% CI 1.015-1.054, $P < 0.001$), insulin-dependent diabetes (adj. OR 3.174, 95% CI 1.665-6.052, $P < 0.001$), the EuroScore II (adj. OR 1.049, 95% CI 1.016-1.083, $P = 0.03$), reoperation for bleeding (adj. OR 1.939, 95% CI 1.053-3.572, $P = 0.034$) and operation within a contaminated TEE period (adj OR 1.558, 95% CI 1.078-2.253, $P = 0.018$) remained independently associated with the development of an infection.

3.5 | Complications and outcome

Thirty-one patients died within 30 days of the index surgery (3.2%) and further three after that while still in hospital (in-hospital mortality 3.5%). Of those who died within 30 days, the most common

TABLE 1 Preoperative and surgical characteristics of 973 consecutive patients undergoing cardiac surgery in Iceland

Patient characteristics (n = 973)		
Preoperative		
Age (mean)	66.7 y	SD 11.50
Males	76%	
Weight (mean)	86.1 kg	SD 15.67
Chronic lung disease[a]	77	7.9%
Extracardiac arteriopathy[b]	58	6.0%
Insulin-dependent diabetes mellitus	51	5.2%
Dialysis dependent	13	1.3%
Angina pectoris at rest	134	13.8%
Recent myocardial infarction[c]	178	18.3%
Critical pre-op condition[d]	48	4.9%
LV Ejection fraction (mean)	53%	SD 11.0
NYHA class[e]		
0	94	9.7%
I	97	10.0%
II	357	36.7%
III	238	24.5%
IV	187	19.2%
Surgical		
Procedure[f]		
CABG	483	49.6%
AVR	156	16.0%
CABG + valve	113	11.6%
Aortic surgery	61	6.3%
MVR	29	3.0%
OPCAB	26	2.7%
Others	105	10.8%
Duration of procedure (mean)	242 min	SD 90.8
Re-do procedure	25	2.6%
Active endocarditis[g]	18	1.8%
Urgency[h]		
Elective	511	52.5%
Urgent	386	39.7%
Emergency	68	7.0%
Salvage	8	0.8%
EuroScore II (median)	1.82	IQR 1.07-3.77
EuroScore II (mean)	3.78	SD 5.8

causes of death were: Cardiovascular (13 patients), infectious (12 patients), stroke (two patients) and unknown (four patients). The most frequent complications were new-onset atrial fibrillation (31.6%), infections (20.3%) and the need for pleurocentesis (10%). Apart from atrial fibrillation and pericardiocentesis, all complications were associated with an increased risk of death on a univariate analysis, see Table 4.

TABLE 1 (Contiuned)

[a]Long-term use of bronchodilators or steroids for lung disease.
[b]One or more of the following: carotid occlusion or >50% stenosis, amputation for arterial disease, previous or planned intervention on the abdominal aorta, limb arteries or carotids.
[c]Myocardial infarction within 90 d.
[d]Critical preoperative state: Ventricular tachycardia or ventricular fibrillation or aborted sudden death, preoperative cardiac massage, preoperative ventilation before anaesthetic room, preoperative inotropes or IABP, preoperative acute renal failure (anuria or oliguria <10 mL/h).
[e]New York Heart Association class.
[f]AVR, aortic valve replacement; CABG, Coronary artery bypass grafting; MVR, mitral valve replacement; OPCAB, Off-pump coronary bypass.
[g]Active endocarditis: Patient still on antibiotic treatment for endocarditis at time of surgery.
[h]Elective: Routine admission for operation. Urgent: Patients who have not been electively admitted for operation but who require intervention or surgery on the current admission for medical reasons. Emergency: Operation before the beginning of the next working day after decision to operate. Salvage: Patients requiring cardiopulmonary resuscitation (external cardiac massage) en route to the operating theatre or prior to induction of anaesthesia.

The median length of stay in the ICU was 1 day (IQR 1-2) and in hospital was 8 days (IQR 7-12). In patients extubated within 24 hours, extubation time was at a median of 6 hours and 32 minutes post-surgery (IQR 4:30-8:52). Re-admissions to the ICU were 42 (4.3%).

Infected patients had a longer duration of stay in the ICU (median 2 days, IQR 1-6) than patients without an infection (median 1 day, IQR 1-1, $P < 0.001$) and they also had a longer duration of stay in the hospital, median 14 days (IQR 9-27.8) vs 8 days (IQR 7-10, $P < 0.001$). Patients who developed a post-operative infection had a higher 30-day mortality rate (8.1%) compared with 1.9% for non-infected patients (OR 4.454, 95% CI 2.162-9.176, $P < 0.001$). The highest 30-day mortality rates were encountered in patients with bloodstream infections (19%, 95% CI 8.2-36.7) and pneumonia (17%, 95% CI 10.5-26.0).

4 | DISCUSSION

We report epidemiological data on post-operative infections and outcomes from a nationwide cohort of cardiac surgery patients. During the study period, there were two large outbreaks of infections associated with damaged and contaminated TEE probes, which had a major effect on our infection rates.

The total infection rate (20.3%) at our institution is higher than has been reported in recent large cardiac surgery cohorts (13.3%[7]-14%[9]). We report a particularly high pneumonia incidence (13.8%) from periods with a damaged TEE probe in use but the incidence in other periods (6.6%) is within the range others have reported (2.4%-10.7%).[3,6,9,13,14]

The rates of other infections, such as surgical site infections (5.7%), bloodstream infections (2.8%), deep sternal infection (1.7%) and symptomatic urinary tract infections (1.4%) are similar to reports from other centres.[3,8,9] Analysis of our data confirms previously

TABLE 2 Post-operative infections diagnosed in 973 consecutive cardiac surgery patients in Iceland

Post-operative infections (n = 973)		
Pneumonia	89	9.1%
With positive cultures	61	6.2%
Clinical diagnosis only	28	2.9%
Surgical site infection	73	7.3%
Deep sternal	17	1.7%
Superficial (sternum or vein harvest site)	56	5.7%
Urinary tract infection	52	5.3%
Symptomatic	14	1.4%
Asymptomatic bacteriuria	38	3.9%
Bloodstream infection	27	2.8%
Endocarditis[a]	5	0.5%
Clostridium difficile enterocolitis	3	0.3%
Others	24	2.4%

[a]Patients who developed endocarditis post-operatively in a valve prosthesis. Patients with endocarditis prior to surgery not included.

known risk factors for the development of an infection, such as age, duration of procedure and insulin-dependent diabetes mellitus, but we are the first to report increased infection rates related to which TEE probe was in use at the time of surgery. This is (to the authors knowledge) the largest reported outbreak related to TEE use and the first with several fatalities.

At the height of the *K oxytoca* outbreak, 16.2% of all cardiac surgery patients had the pathogen in a respiratory tract sample (Figure 3) and 61% of all respiratory tract samples from cardiac patients were positive for *K oxytoca* (microbiology cultures were only taken on clinical suspicion of an infection). The bacteria therefore seems to have been very efficient at colonising the respiratory tract of exposed patients. Several factors may have aided this. The TEE probe slides past the laryngeal inlet on insertion and is routinely left in place for several hours during surgery. Host defence mechanisms are also compromised due to numerous factors, such as general anesthesia, endotracheal tube, atelectasis, sedative drugs and the stress of a major operation. This efficiency of respiratory tract colonisation and subsequent development of pneumonia suggests that aspiration of secretions from the pharynx or oesophagus into the respiratory tract during surgery and intubation may be more common

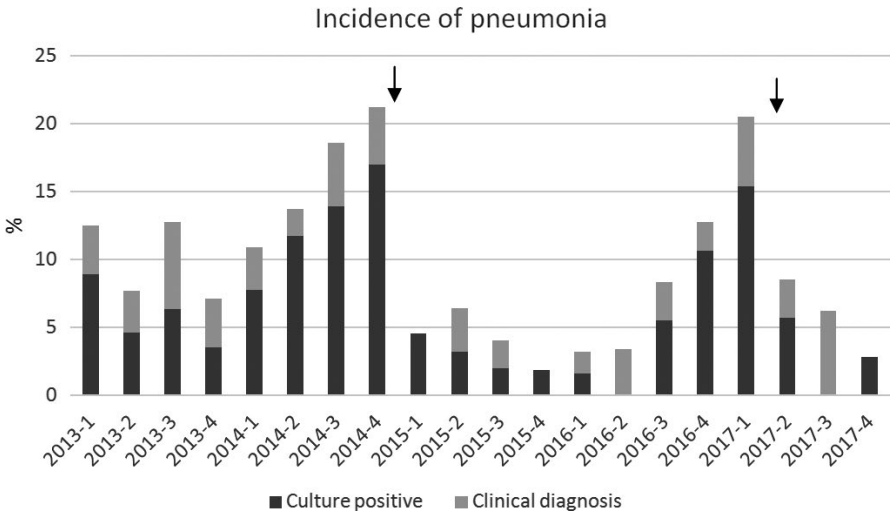

FIGURE 2 Incidence of pneumonia after cardiac surgery over a 5-year period. Each column represents one quarter year. Arrows indicate the time of TEE probe changes (November 2014 and April 2017)

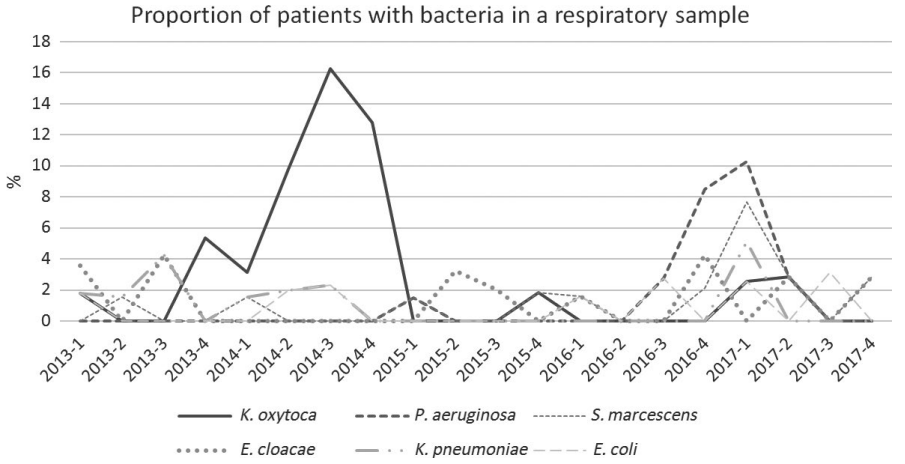

FIGURE 3 The figure shows the proportion of all cardiac surgery patients with specific bacteria isolated from a post-operative respiratory sample

TABLE 3 Presented in the table are factors associated with the development of post-operative infection in a cohort of 973 cardiac surgery patients

Risk factors for developing a post-operative infection—a univariate analysis				
Variable	**Infected (n = 198)**	**No infection (n = 775)**	**Unadj. OR (95% CI)**	***P*-value**
Duration of procedure	279 min (SD 121.1)	233 min (SD 78.7)	1.005 (1.003-1.006)	**<0.001**
Age (y)	69.8 (SD 10.48)	65.9 (SD 11.62)	1.034 (1.018-1.050)	**<0.001**
Extracardiac arteriopathy[a]	18 (9.1%)	40 (5.2%)	1.837 (1.029-3.281)	**0.040**
Critical pre-op condition[a]	20 (10.1%)	28 (3.6%)	2.998 (1.651-5.444)	**<0.001**
Insulin-dep. diabetes mellitus	20 (10.1%)	31 (4.0%)	2.697 (1.502-4.843)	**0.001**
NYHA class				
0	17 (8.6%)	77 (9.9%)	Reference	
I	13 (6.6%)	84 (10.8%)	0.701 (0.320-1.538)	0.375
II	50 (25.3%)	307 (39.6%)	0.738 (0.403-1.350)	0.324
III	57 (28.8%)	181 (23.5%)	1.426 (0.780-2.609)	0.249
IV	61 (30.8%)	126 (16.3%)	2.193 (1.194-4.027)	**0.011**
Angina at rest	37 (18.7%)	97 (12.5%)	1.606 (1.060-2.435)	**0.026**
Ejection fraction	50.1% (SD 12.20)	54.1% (SD 10.49)	0.970 (0.956-0.984)	**<0.001**
Pulm. art. pressure[b]	42 mm Hg (SD 12.7)	38 mm Hg (SD 13.4)	1.024 (1.005-1.043)	**0.015**
Recent MI[a]	48 (24.2%)	130 (16.8%)	1.588 (1.090-2.312)	**0.016**
Urgency of procedure[a]				
Elective	94 (47.4%)	417 (53.8%)	Reference	
Urgent	76 (38.4%)	310 (40.0%)	1.088 (0.777-1.522)	0.625
Emergency	26 (13.1%)	42 (5.4%)	2.746 (1.604-4.702)	**<0.001**
Salvage	2 (1.0%)	6 (0.8%)	1.479 (0.294-7.441)	0.635
Euroscore II	2.9 (IQR 1.62-8.70)	1.6 (IQR 1.00-3.10)	1.096 (1.066-1.127)	**<0.001**
Reoperation for bleeding	21 (10.6%)	43 (5.5%)	2.020 (1.169-3.490)	**0.012**
Contaminated TEE period[c]	79 (40.1%)	249 (32.1%)	1.402 (1.016-1.935)	**0.040**

[a]See definitions under Table 1.
[b]The pulmonary arterial pressure was excluded from the multivariate analysis due to a large number of missing values.
[c]Operation in a time period where a damaged and contaminated TEE probe was in use.
Statistically significant values in bold ($P < 0.05$)

than is generally appreciated. This risk may be increased when a TEE probe is used concurrently.

The clinical presentation of infections related to TEE use was in most cases an early-onset pneumonia within 3 days of surgery. Interestingly, no patient with *K oxytoca* had a bloodstream infection and there were no fatalities directly attributed to the *K oxytoca* infections. The *P aeruginosa* seemed to be more virulent, with 3 of 10 patients developing bloodstream infection with septic shock. *P aeruginosa* has been associated with a higher mortality than other pathogens in previous studies on post-operative pneumonia.[27]

The *K oxytoca* outbreak went unnoticed for some time in our institution. The Department of infection control has an active surveillance system for several pathogens, such as extended spectrum beta-lactamase (ESBL) producing strains of Enterobacteriaceae, but the *K oxytoca* did not produce ESBL even though it was multidrug resistant. The patient cohort was cared for post-operatively in a general mixed ICU where the majority of physicians have short rotations and this may have hindered detection of the outbreak. The discovery of the *P aeruginosa* outbreak was quicker. Although *P aeruginosa* is a relatively common pathogen in the ICU, the unusual clinical presentation of septic shock in two post-operative cardiac patients within a short period led to an alert to infection control.

Our experience with two damaged probes over a relatively short time period suggests that TEE probe damage causing decontamination failure may be more common than is appreciated and that this damage can be difficult to detect. The use of protective sheaths on the TEE probe reduces the risk of cross-infection in case there is a decontamination failure. However, sheaths can be impractical as some users find they impair ultrasound views of the heart and not all sheaths are robust enough to maintain integrity during a lengthy surgery. We made informal enquiries to centres in both Europe and the United States of America and in most cases protective sheaths were not used on TEE probes during cardiac surgery. In collaboration with the Department of Infection Control, we have enhanced cleaning routines for TEE probes, which now include ultraviolet light decontamination and regular visual examination under magnification and enhanced lighting for signs of damage. The use of probe sheaths is now mandatory at our clinic.

TABLE 4 Rates of complications in 973 consecutive cardiac surgical patients in Iceland and their impact on survival in a univariate analysis with 30 d mortality as the dependent factor

Rates of complications and risk of death after cardiac surgery				
Complications	**n**	**%**	**Unadj. OR for 30 d mortality (95% CI)**	***P*-value**
New-onset atrial fibrillation	307	31.6	0.888 (0.404-1.953)	0.768
Infection (any)	198	20.3	4.454 (2.162-9.176)	**<0.0001**
Pleurocentesis	97	10.0	2.761 (1.157-6.587)	**0.022**
Mech. ventilation >48 h	83	8.5	13.930 (6.600-29.400)	**<0.0001**
Reoperation for bleeding	64	6.6	2.878 (1.067-7.767)	**0.037**
Mechanical assist device	49	5.0	18.176 (8.271-39.941)	**<0.0001**
Re-intubation	37	3.8	13.354 (5.640-31.617)	**<0.0001**
Pericardiocentesis	27	2.8	1.174 (0.154-8.943)	0.877
Cerebrovascular accident	22	2.3	7.605 (2.410-23.994)	**<0.0001**
Renal replacement therapy[a]	17	1.7	20.313 (6.960-59.284)	**<0.0001**
Reoperation for graft failure	6	0.6	na	na

[a]Aorta balloon pump or venoarterial extracorporeal membrane oxygenation (VA-ECMO) post-operatively.
[b]For post-operative acute kidney injury.
Statistically significant values in bold ($P < 0.05$)

We cannot exclude that the high pneumonia rates we observed may have influenced the rates of other complications, such as the need for pleurocentesis (10%) and mechanical ventilation >48 hours (8.5%). Both were higher than the corresponding rates published in the Swedeheart 2017 Annual report (6.3% and 5.1% respectively).[10] The Swedeheart Annual report publishes outcome data annually from around 6000 cardiac operations in Sweden, with patient characteristics and EuroScore II (mean 3.1%-5.1%) very similar to the cohort described in our study (3.78%). The rates of other complications such as cerebrovascular accidents (2.3%) and renal replacement therapy (1.7%) were similar to those reported in Swedeheart (2.0% and 3.0% respectively), as was the 30-day mortality, 3.2% vs 1.6%-3.5% in the Swedeheart cohort.

The strength of this study is the nationwide cohort from a single institution over a 5-year period. Rather than relying on diagnostic codes, we reviewed the charts of every cardiac patient during the study period. A limitation is the retrospective design and the inherent difficulties in diagnosing infections retrospectively. Especially pneumonia can be difficult to ascertain, given that critically ill cardiac surgery patients invariably have infiltrates on their chest X-rays and frequently exhibit a *systemic inflammatory response syndrome* post cardiopulmonary bypass.

5 | CONCLUSIONS

Minor surface damage and subsequent contamination of TEE probes were responsible for a surge in pneumonia rates and bloodstream infections with fatal outcomes in cardiac surgery patients in Iceland. This study highlights the importance of TEE probes as a potential risk factor for pneumonia following cardiac surgery and the necessity of adequate procedures for handling, inspection and decontamination of TEE probes.

ETHICS APPROVAL

The study was approved by the National Bioethics Committee of Iceland, the Icelandic Data Protection Authority and the chief medical executive of Landspitali University Hospital. The need for informed consent was waived given the observational nature of the study.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The datasets analysed in the current study are available from the corresponding author on reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTIONS

E. V. and S. K. designed the study. E. V. and K. O. H. collected patient data. E. V. did statistical analysis. All authors co-wrote the manuscript.

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