Review Article

Transesophageal echocardiography-related complications

[Complications associées à l'échocardiographie transoesophagienne]

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Purpose: The use of transesophageal echocardiography has increased over the past several years. It is generally considered a safe diagnostic and monitoring tool. Whereas complications associated with echocardiographic examination rarely occur, such complications must be known to echocardiographers performing these examinations. The purpose of this review is to summarize potential complications associated with transesophageal echocardiography.

Sources: A systematic search of the English and French literature was undertaken using PubMed from the National Library of Medicine. Relevant articles were obtained from a Medline search spanning the years 1975 – 2007, and their reference lists were used to retrieve additional articles.

Principal findings: Complications of transesophageal echocardiography are primarily related to the gastrointestinal, cardiovascular, and respiratory systems, and include infection, toxic drug reaction, local reaction through contamination of the probe, and ultrasound cavitation. Strategies to prevent these complications are reviewed.

Conclusion: Whereas transesophageal echocardiography is associated with a low complication rate, the echocardiographer must be knowledgeable about the types of complications and their predisposing factors, and should be meticulous in preventing their occurrence.

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Objectif *: Au cours des dernières années, l'utilisation de l'échocardiographie transoesophagienne a augmenté. Cette modalité est en général considérée comme un outil de diagnostic et de monitorage sécuritaire. Bien que des complications associées à un examen échocardiographique ne surviennent que rarement, il est néanmoins important que les échocardiographistes en soient conscients. L'objectif de ce compte-rendu est de résumer les complications potentielles associées à l'échocardiographie transoesophagienne.*

Sources *: Une recherche systématique de la littérature en anglais et en français a été menée dans la base de données PubMed de la Bibliothèque nationale de médecine américaine. Les articles pertinents ont été extraits d'une recherche Medline couvrant la période 1975-2007, et leurs listes de références ont été utilisées pour récupérer d'autres articles pertinents.*

Constatations principales *: Les complications associées à l'utilisation de l'échocardiographie transoesophagienne sont principalement liées aux systèmes gastro-intestinal, cardiovasculaire et respiratoire. Elles comprennent l'infection, la réaction toxique au médicament, la réaction locale en raison d'une contamination de la sonde, et la cavitation des ultrasons. Les différentes stratégies pour prévenir ces complications sont passées en revue.*

Conclusion *: Bien que l'échocardiographie transoesophagienne soit associée à un faible taux de complications, l'échocardiographiste doit connaître les différents types de complications ainsi que les facteurs les prédisposant, et devrait apporter un soin particulier à les prévenir.*

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Table of contents

Transesophageal echocardiography (TEE) is a very useful, semi-invasive diagnostic and monitoring technique. Since the initial work published by Frazin in 1976,[1] there has been a substantial increase in comprehensive knowledge of cardiovascular anatomic and hemodynamic correlations, as well as progress and innovation in the technique. Transesophageal echocardiography is presently in widespread use in ambulatory clinics, coronary care units, intensive care units (ICUs), and operating rooms. Examinations using TEE are considered safe when conducted in a controlled environment by trained operators.[2] Information obtained from TEE can have a significant impact in cardiac[3–9] and non-cardiac surgery,[10–12] as well as in making decisions in the ICU.[11,13,14] Considering the widespread application of this technique, it is important to address the issue of safety. In this article, we present a comprehensive review of the literature pertaining to TEE complications reported during examinations undertaken in cardiology suites, operating rooms, and ICUs. We also suggest strategies aimed at the prevention of TEE-related complications.

Literature search strategy

A systematic search of the English and French literature was performed using the database PubMed from the National Library of Medicine. Literature was searched for the period 1975 to 2007. The bibliography of each article was then reviewed to seek additional references and to produce a detailed reference list. The term 'transesophageal echocardiography' was paired with the following MeSH keywords: 'adverse effects', 'complications', 'injuries', 'safety', 'esophagus/hypopharynx injuries', 'endoscopy', 'intoxication', and 'infection/bacteriemia'.

Articles describing experiences with the use of TEE were reviewed for reported complications. In addition, for completeness, articles reviewing complications in relation to upper airway endoscopy were retrieved, because the latter procedure is similar to probe insertion with TEE. Additional references from the endoscopy literature were inserted when pertinent to the discussion. Using that strategy, 207 references were reviewed. A total of 30 reports of patients with perforations and 14 reports of patients with bleeding are described in Table I. Complications were reviewed in 17 adult databases, representing 42,355 patients, and one pediatric database of 1,650 patients (Table II). Figure 1 summarizes the TEE-related complications.

I- Gastrointestinal complications

Tolerance and airway reflexes

Retching commonly occurs during TEE examination in awake subjects, with a reported incidence of 39%.[15] In ambulatory TEE procedures, sedation, local anesthesia, and transtracheal block[16] can improve patients' tolerance and reduce the severity and duration of retching. Patients experiencing retching complain mostly of having a sore throat. During TEE examination, elderly patients manifest a reduction of the physiological gag reflex as compared to younger subjects.[15,17] Mallory-Weiss syndrome, which is associated with forceful vomiting efforts, has been reported in the endoscopy and TEE literature.[18,19] In the presence of intractable gasping or vomiting, TEE examination should not be pursued, and sedation and analgesia plans should be re-evaluated. A lack of tolerance to probe placement is often the reason for failed esophageal intubation or for a premature termination of the procedure in the awake state.[2,20] Complications associated with forceful retching and gasping create a Valsalva maneuver response, the hemodynamic effects of which will be discussed in Section II: Cardiovascular system complications.

Occult gastroesophageal lesions and anatomic variations

Occult gastroesophageal lesions and anatomic changes are risk factors for complications associated with TEE probe insertion. Elderly patients are more likely to suffer occult esophageal lesions such as diverticula,[2,20] arthritic mechanical modification of the cervical spine,[21,22] hiatal hernia, neoplasms, or inflammatory mucosal changes. The evaluation of patients should always include specific inquiries related to gastroesophageal symptoms such as dysphagia that could reveal an underlying, yet undiagnosed, abnormality.

It is at the level of the cricopharyngeal muscle that esophageal intubation most often fails. The prominence of the cricoid muscle can be an obstacle for esophageal intubation, as is the presence of cervical

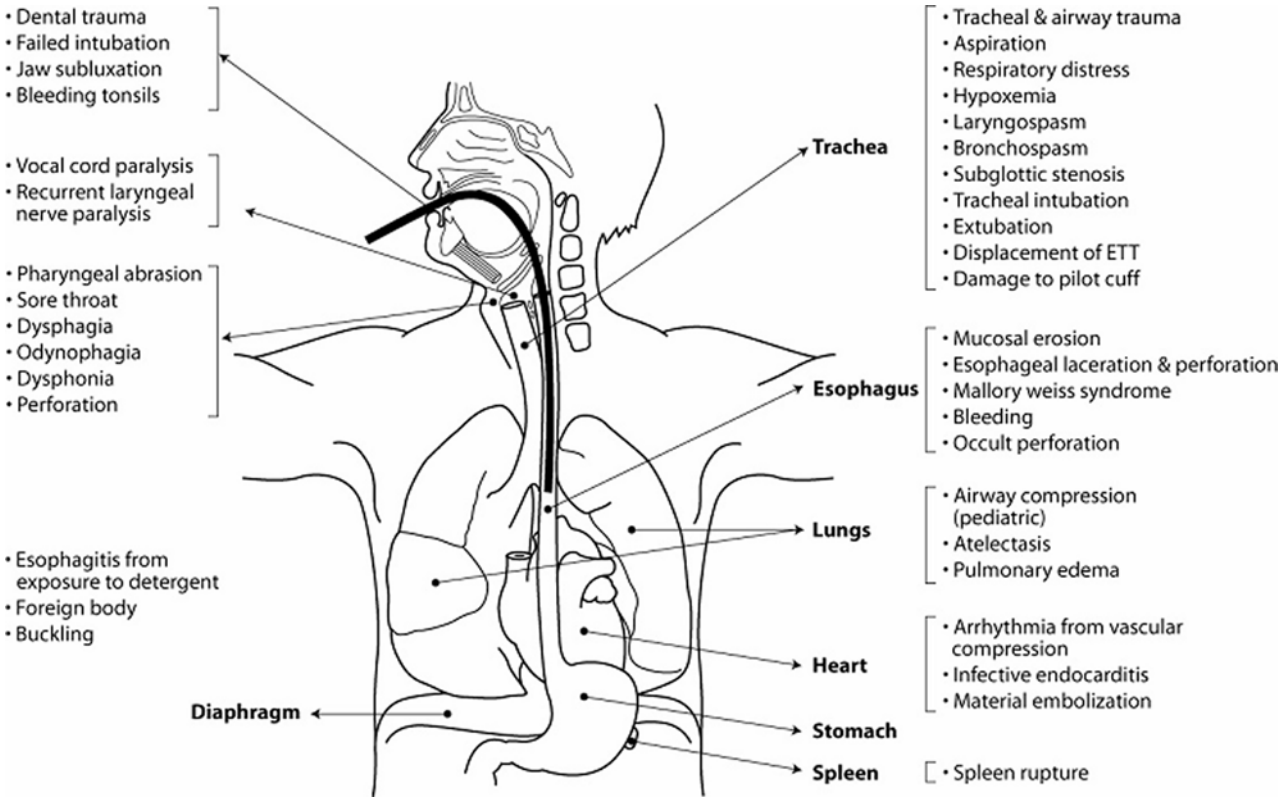

FIGURE 1 Transesophageal echocardiography (TEE)-related complications (ETT = endotracheal tube). With permission from Informa Healthcare (Denault *et al.* 2005).

osteophytosis.[21] Schatzki's ring (a diaphragm-like thin mucosal ring, usually located at the squamocolumnar junction, with an incidence of 10% in the general population) can complicate TEE due to esophageal narrowing. This complication can be predicted by dysphagia occurring in about 30% of patients when the esophageal diameter is less than 12 mm. Prior cervical surgery, such as extensive resection or laryngectomy, may also produce an anatomical distortion of the region[23] requiring special care during probe insertion.

During esophageal intubation, the probe may slide repeatedly into a Zenker's or a Killian-Jamieson diverticulum. The former is located on the posterior pharyngoesophageal wall above the cricopharyngeus.[24] The latter originates on the anterolateral wall of the proximal cervical esophagus below the cricopharyngeus and lateral to the longitudinal tendon of the esophagus. Depending on the size and depth of the diverticulum, a variable length of the probe will be inserted until resistance is felt. An esophageal diverticulum may easily be perforated during forceful insertion, thus increasing the risk of morbidity. To avoid such a risk, several techniques have been reported and have documented the safe use of TEE in patients with a known diagnosis of Zenker's diverticulum.[25–28]

Disorders that can reduce the esophageal lumen and complicate TEE include esophageal achalasia (i.e., a failure of the lower esophageal sphincter to relax), Barrett's esophagus, chemical esophagitis, late scleroderma, Chagas disease, and benign as well as malignant esophageal tumours that can erode and bleed.[2] Peptic ulcer and gastroesophageal reflux can also cause esophageal stricture and erosion that complicate TEE examination.[29]

Unexpected difficulties have been encountered in patients with hiatal hernia.[30] A fluid-filled hiatal hernia can appear as a thick-walled cystic mass posterior to the left atrium.[31] Air-fluid level within a hiatal hernia can produce ultrasound propagation and shadowing of more anterior structures, thus making TEE technically difficult.[31] A sliding hiatal hernia is more common than a paraesophageal hernia, but neither is a contraindication to TEE. In the sliding hernia, the gastroesophageal junction and a portion of the fundus of the stomach slide upwards into the thorax. In contrast, in the paraesophageal hernia, only the fundus of

TABLE I Reported cases of esophageal perforation and bleeding after TEE procedures

Author	*Patients*	*Pre-TEE GI Symptoms*	*Setting*	*Technical characteristics (No of attempts)*	*Lesion localization (from teeth)*	*Presentation*	*Diagnosis delay*	*Modality of diagnosis*	*Treatment conclusion*	*Results*
PERFORATION										
El-Chami, 2006[206]	M 52	none	NR	Resistance felt at 30 cm	Esophageal dissection	Asymptomatic	none	Barium swallow	Conservative	Alive
Min, 2005[207]	M 73	None	Sedation	Difficult intubation	Sinus pyriform	Hemoptysis Dyspnea	12 hr	Chest *x-ray* CT scan	Surgical repair	Alive
Min, 2005[207]	M 79	Peptic ulcer	Sedation	Difficult intubation	Cervical esophagus	Sore throat	4 hr	Chest *x-ray* Esophagram	Surgical repair	Alive
Min, 2005[207]	F 84	GER	Sedation	Difficult intubation	Cervical esophagus	Dyspnea Cough Odynophagia Dysphagia	22 hr	Chest *x-ray* CT scan	Surgical repair	Alive
MacGregor, 2004[208]	F 72	Gastritis	GA	Easy	Gastroesophageal junction Mallory-Weiss tear	Anemia	2 days	Esophagoscopy	Epinephrine injection	Alive
MacGregor, 2004[208]	F 79	NR	GA	Easy	Distal esophagus	Pleural effusion	6 days	Esophaoram	Surgical repair	Alive
Sobrino, 2004[209]	F 90	NR	Sedation	Resistance felt	Zenker's diverticulum	Right chest pain Subcutaneous emphysema	After TEE exam	Chest *x-ray*	Surgical placement of gastric tube	Alive
Aviv, 2004[210]	NR	NR	Sedation	NR	Hypopharyngeal perforation	Dysphagia, Odynophagia, Fever, Neck swelling	18 hr	Barium swallow	Surgical repair	Alive
Aviv, 2004[210]	NR	NR	Sedation	NR	Hypopharyngeal perforation	Dysphagia, Odynophagia, Hematemesis	During exam	Esophagoscopy	Conservative	Alive
Han, 2003[49]	M 61	None	GA	Resistance at 30 cm from incisors Probe left at this level	Middle third of the esophagus	Sepsis	12 days	CT	Surgical repair	Alive
Pong, 2003[45]	F 62	NR	GA	Easy	Middle esophagus adjacent to calcified nodule	Pleural effusion	4 days	Upper GI series	Surgical repair	Died, PO #182, intracranial hemorrhage
Nana, 2003[211]	F 70	NR	GA	Easy	Distal esophagus	Fever, anemia and pleural effusion	2 days	CT and esophagoscopy	Esophageal stent	Alive

TABLE I Reported cases of esophageal perforation and bleeding after TEE procedures (*continued*)

Author	*Patients*	*Pre-TEE GI Symptoms*	*Setting*	*Technical characteristics (No of attempts)*	*Lesion localization (from teeth)*	*Presentation*	*Diagnosis delay*	*Modality of diagnosis*	*Treatment conclusion*	*Results*
Zalunardo, 2002[59]	M 72	NSAID	GA	Easy	Lower esophagus	Pleural effusion Neutrophilia Deterioration Nutrition fluid from chest drains	8 days	Esophagram	Surgical repair Esophageal stent	Alive
Law-Koune, 2002[212]	F 77	NR	GA	Easy	Upper esophagus	Intraoperative perforation	None	Probe in the surgical field and esophagram	Surgical repair	Dead
Lecharny, 2002[60]	M 37	NR	GA	TEE lasted 9 hr	Esophagotracheal perforation	Shock	7 days	Ventilation leak + Esophagoscopy	Blackmore esophageal balloon catheter Died before surgery	Dead
Brinkman, 2001[213]	F 80	NR Low dose steroid	GA	Easy	Lower esophagus	Fever, pleural effusion Burning	> 1 month	CT Esophagram	Surgical placement of T-tube	Alive
Brinkman, 2001[213]	F 70	NR Radiotherapy for breast cancer	GA	Easy	Mid-esophagus	Burning substernal pain	Few hours	Esophagram	Surgical repair	Alive
Brinkman, 2001[213]	F85	NR	GA	Easy	Mid-esophagus	Pleural effusion	2 days	Chest *x-ray* fluid, gastrointestinal content from chest tube	Surgical repair	Alive
Muhiudeen, 2001[214]	N = 3	Regurgitation	GA	Easy, (2)	Cricoid muscle	TEE surgical field	Immediately	TEE surgical field	Medical	Alive
Massey, 2000[33]	F 59	None		Easy Resistance felt at 30 cm	Esophageal tear at 39 cm with abscess	Pleuretic pain	4 days	Chest *x-ray* fluid + Esophagoscopy	Surgical repair	Dead, day 9
MacGowan, 2000[58]	M 64	NR	GA	Easy	Esophageal ulceration with left bronchial fistula	Sepsis	Autopsy		Autopsy	Dead, day 19
Jougon, 2000[57]	M 86	NR	LA		Cervical esophageal at 19 cm	Rapid sepsis	Few hours	Esophagram + Esophagoscopy	Esophagostomia	Dead
Jougon, 2000[57]	F 65	NR	LA	Difficult	Cervical esophageal at 15 cm	S/C emphysema	Post-examination	Esophagoscopy	Esophagostomia	Alive
Kallmeyer, 2001[55]	F 81	NR	GA	Easy		Dyspnea	2 days	Chext *x-ray* + Esophagram	Surgical repair	Alive
Lalanne, 1996[56]	F74	NR	LA	Easy	Mid-esophagus	Dyspnea Chest pain Epigastralgia	Immediately		Surgical repair	Dead, sepsis PO#2
Spahn, 1995[195]	F 75	NR	GA	NR	Pharyngeal	TEE surgical field	Immediately	TEE surgical field + Esophagoscopy	Surgical suture	Alive
Badaoui, 1994[19]	F 71	NR	LA	Difficult (3)	Laceration at 2-3 cm	Cervical pain S/C emphysema	Few hours	Esophagram	Esophagostomia	Alive
Daniel, 1991[2]	F 61	Thrombolysis		NR	Intra-mural hematoma with rupture in the thorax	Shock	4 hr	Surgery	Surgery	Alive
BLEEDING										
Kerbaul, 2004[215]	M 41	NR	GA	2 attempts difficult progression beyond 35 cm	2 esophageal perforations	Upper GI hemorrhage Shock	Immediately after probe removal and insertion of NG tube	Esophagoscopy	Surgical repair	Died, from multiple organ failure

TABLE I Reported cases of esophageal perforation and bleeding after TEE procedures (*concluded*)

Author	*Patients*	*Pre-TEE GI Symptoms*	*Setting*	*Technical characteristics (No of attempts)*	*Lesion localization (from teeth)*	*Presentation*	*Diagnosis delay*	*Modality of diagnosis*	*Treatment conclusion*	*Results*
Massa, 2003[68]	F 78	NR	Sedation	Easy	Supraglottic hematoma	Complain of sore throat (5 hr post-procedure) Hemoptysis Hoarseness Inspiratory stridor	11 hr	Flexible nosopharyngo-laryngoscopy	Awake tracheostomy	Alive
Kallmeyer, 2001[55]	M	Zenker	GA	Easy	Erosion at GE junction + Mallory-Weiss syndrome	Upper GI hemorrhage (> 600 mL)	Immediately after probe removal	Esophagoscopy	Medical	Alive
Kallmeyer, 2001[55]	M		GA	Easy	Erythema and diffuse oozing from the GE junction	Upper GI hemorrhage (> 600 mL)	Immediately after probe removal	Esophagoscopy	Medical	Alive
De Vries, 2000[64]	M 74	None	GA	Easy	GE Mallory-Weiss syndrome	Upper GI hemorrhage (> 3000 mL)	Immediately after probe removal	Esophagoscopy	Epinephrine injection	Dead, 90 days after, from multi-organ failure
Kihara, 1999[216]	M 46	None	GA	Easy	Gastric tear 2 cm from the GE junction	Upper GI hemorrhage	On ICU arrival	Esophagoscopy	Endoscopic argon plasma coagulation Medical	Alive
Shapira, 1999[217]	F 80	None	LA	Easy	Cricoid level	Thoracic pain Bloody vomitus S/C emphysema	Immediately after probe removal	Esophagram + Scan	*iv* AB + NPO	Dead
St-Pierre, 1998[46]	M 50	None	GA	Easy	GE Mallory-Weiss syndrome	Upper GI hemorrhage (1200 mL red blood)	Immediately after probe removal	Esophagoscopy	Epinephrine injection	Alive
Kharasch, 1996[48]	F 66	None	GA	Easy	Esophageal	Abdominal pain Upper GI hemorrhage (600 mL red blood)	20 hr PO	Esophagoscopy	Esophagostomia	Alive
Latham, 1995[44]	M 65	None	GA	Easy	Laceration of cardia	Upper GI hemorrhage (> 600 mL red blood)	Immediately after probe removal	Esophagoscopy	Medical	Alive
Savino, 1994[218]	M 83	None	GA	Difficult	Pharyngeal	Bleeding from mouth, chest tube	On ICU arrival	Oropharyngeal examination	Throat pack	Dead, day 3 Sepsis
Polhamus, 1993[219]	F 73	Osteoarthritis anticoagulation	LA	NR	3 cm above the LES	Upper GI hemorrhage	4 days	Esophagoscopy	Medical	
Daniel, 1991[2]	F 61		LA	NR	Tumour	Bleeding	Immediately	Autopsy		Dead
Dewhirst, 1990[43]	F 77	Gastritis	GA	Easy	GE syndrome Mallory-Weiss	Upper GI hemorrhage (500 mL red blood)	on ICU arrival	Esophagoscopy	Medical	Alive

AB = antibiotics; ARF = respiratory failure; CT = computed tomography; Esoph = esophagus; F = female; GA = general anesthesia; GE = gastro esophageal junction; GI = gastro-intestinal; ICU = intensive care unit; L = Left; LA = local anesthesia; LES = lower esophageal sphincter; M = male; N = number; Nb = newborn; NPO = nil per os; NR = not reported; NSAID = non-steroidal anti-inflammatory agents; PO = postoperative; S/C = subcutaneous; TEE = transesophageal echocardiography.

TABLE II Studies reporting TEE complications

Reference	*Number of TEE*	*Awake/ GA (%)*	*Total %*	*Mortality %*	*Failed intubation* %*	*Complications reported*
Gurbuz, 2007 [8]	744	0/100	0	0	0	Sore throat and odynophagia in 91 patients (0.12%)
Kallmeyer, 2001[55]	7,200	0/100	0.2 (14)	0	0 (13)	Endotracheal tube malposition (2), upper GI bleeding (2), esophageal perforation (1), dental injury (2), odynophagia (7)
Click, 2000[5]	3,245	0/100	0	0	1.6	
Mishra, 1998[4]	5,016	0/100	0.08	0	0.08 (4)	
Suriani, 1998[10]	123	100/0	0	0	0	
Sutton, 1998[3]	238	0/100	0	0	0	
Tam, 1997[21]	2,947	100/0	2.9 (86)	0.3 (1)	1.4 (40)	Tracheal intubation (9), pulmonary edema (2), bleeding (9), angina (2), supraventricular tachycardia (1), superficial thrombophlebitis (2), intolerance (27)
Chee, 1995[40]	901	98/2	0.6 (5)	0	1.2 (10)	Buckle (2), GI bleeding (1), cerebrovascular accident (1), jaw dislocation (1)
Rafferty, 1993[39]	846	0/100	0.7 (6)	0	0	Chipped tooth (1), pharyngeal abrasion (3), unilateral vocal cord paralysis (1), glutaraldehyde contamination (1)
Vignon, 1993[20]	1,500	100/0	3.5 (52)	0	1.6% (24)	Tracheal intubation (2), CHF (1), pharyngeal hemorrhage (2), dysarrythmia (3), vertigo (1), jaw subluxation (1), vomiting (4), intolerance (12), others (2)
Seward, 1992[31]	3,827	100/0	2.9 (111)	0.026 (1)	0.94 (36)	Laryngospasm (5), hypoxia (13), dysarrythmia (22), CHF (2), transient hypotension (13), transient HTN (15), blood-tinged sputum (9), others (31)
Chan, 1991[117]	1,500	100/0	0.47 (7)	0	0.73 (11)	Tracheal intubation (4), auricular fibrillation (2), bronchospasm (1)
Daniel, 1991[2]	10,419	88.7/11.3	2.8 (291)	0.0098 (1)	1.9 (201)	Bronchospasm (6), hypoxia (2), dysarrythmia (7), angina (1), bleeding (2), vomiting (5), intolerance (65), TEE probe defect (2)
Khandheria, 1991[118]	2,070	100/0	1.9 (39)	0,04 (1)	1 (21)	Tracheal intubation (2), laryngospasm (3), pulmonary edema (1), cardiac arrest (2), esophageal pathology (4), hypotension (5)
Cujec, 1989[220]	100	61/39	1 (1)	0	1 (1)	Sore throat
Daniel, 1991[2]	1,300	100/0	2 (27)	0	1.5 (20)	Bronchospasm (1), dysarrythmia (2), vomiting (1), intolerance (3)
Khanderh, 1991[221]	220	100/0	1.4 (3)		0.9 (2)	Dysarrythmia (1), sore throat (65%), midazolam-induced amnesia (87%)
PEDIATRIC TEE						
Stevenson, 1999[75]	1,650	7/93	3.2 (52)	0	0.8 (13)	Airway obstruction (1), endotracheal tube malposition (3), extubation (8), vascular compression (10)

CHF = congestive heart failure; GA = general anesthesia; HTN = hypertension; TEE = transesophageal echocardiography.
*Definition of failed intubation: inability to pass the probe into the esophagus for echographic imaging, despite adequate sedation and topical anesthesia or general anesthesia.

the stomach migrates past the gastroesophageal junction, leaving this junction in its normal location. In patients with total or partial gastrectomy, TEE is not contraindicated as long as the probe is manipulated within the esophagus.[32]

Normal anatomical variants, such as an aortic impression, a large left atrium and left main bronchus, or pathological conditions, such as an enlarged heart, a mediastinal tumour,[33] or esophageal duplication, can compress the esophagus, distort its imaging, and complicate esophageal intubation.[34] Esophageal vascular abnormalities, such as prominent venous plexus or varices associated with cirrhosis and portal hypertension, may cause bleeding during TEE; therefore, TEE should either not be used at all, or should be used with great caution during hepatic transplantation.[35]

Cervical instability, due to trauma or to subluxation at the C1 and C2 levels associated with Down's syndrome or severe rheumatoid arthritis, may make esophageal intubation difficult because of the need for airway management.[36] Careless manipulation of the cervical spine can induce neurological deficits.

Failure to intubate the esophagus

The incidence of failure to intubate the esophagus ranges from 0% to 1.9% (Table II). Factors contribut-

ing to such problems include lack of cooperation or the lack of operator experience, accounting for most cases (98.5%), as well as anatomical abnormalities, accounting for 1.5% of cases.[2] Anatomic abnormalities producing esophageal intubation failure include a double aortic arch,[37] cervical osteophytes[21] and decreased cervical range of motion,[28] swallowing impairment, mucosal abnormalities such as prior radiation exposure or decreased saliva production,[28] prior tracheostomy,[38] and an inflated endotracheal balloon.

Several suggestions have been advanced to overcome failed intubation. Deeper sedation and local analgesia may provide relief from muscular spasm and improve patient cooperation. If resistance at the level of the esophagus is not eliminated by a swallowing effort, the examination should be aborted, and radiological evaluation should be considered in order to rule out anatomical obstruction. In Tam's cohort, for example, cervical spondylosis associated with vertebral spurs was the most common cause of failed intubation in 16 of 40 patients.[21] With anatomic variants such as cervical osteophytes, flexion of the neck may help to overcome the obstruction. In intubated and ventilated patients, the endotracheal tube balloon cuff can be deflated if resistance at the level of the larynx is encountered during probe insertion. In our own experience in such situations, we prefer to intubate under direct vision. Whereas a nasogastric tube rarely impedes intubation, it often leads to sub-optimal image acquisition. Limited mouth opening can also be an obstacle.

Injuries, perforation, laceration and tear of the gastroesophageal tract

Dental trauma,[39] jaw subluxation,[20,40] tonsillar bleeding, erosion, and submucosal hematoma of the pharyngeal area[22,41] are some of the injuries related to TEE probe insertion of the upper gastrointestinal (GI) tract.

Esophageal perforation occurs in the abdominal (57.3%), intrathoracic (33.3%), and cervical (9.3%) portions of the esophagus.[42] It can be caused by poor patient cooperation, inadequate technical skills, unexpected anatomical characteristics (GI abnormalities, extrinsic compression of the esophagus from enlarged left atrium,[33,43,44] a large calcified lymph node,[45] a cervical spur), or mucosal damage (due to motion, local ischemia, or pressure and heat by the probe). The hypopharynx and upper esophagus are the regions most vulnerable to perforation,[41] because the esophageal wall has an intrinsic weakness caused by fibres crossing from the pharyngeal constrictor and the cricopharyngeal muscles. Neck extension, either with or without prominent anterior vertebral osteophytes, can increase the risk of perforation at the hypopharynx and upper esophageal region by stretching the mucosa and muscular fibres. Shearing stress, prolonged flexion of the probe tip, and probe mobilization in a locked position may result in esophageal tearing or perforation. Such complications have been documented endoscopically.[46] Several upper GI injuries related to perioperative TEE were reviewed by Augoustides.[47]

Factors that can contribute to ischemic esophageal wall injury include non-pulsatile flow, prolonged cardiopulmonary bypass,[48] celiac occlusion,[48] distended atrium[49] and mechanical compression,[50] as well as excessive heat from the probe. Whereas pressures of less than 17 mmHg are not expected to be harmful,[51] the TEE probe can sometimes generate pressures of up to 60 mmHg, causing compression and injury. In a recent series, Lennon[52] reported six GI complications, where four involved tears or lacerations of the distal esophagus or proximal stomach, and two involved perforation of gastric cardia. Lacerations of distal esophagus can be explained when the probe is placed in a deep transgastric view position. Gastric cardia would result from either the localization or from the probe when obtaining left ventricular short axis views. Excessive heat generated by the probe can be rapidly transmitted by blood flow, causing thermal injury. To prevent such injuries, a sensor in the probe shuts the system when the temperature exceeds 40°C.

Epidemiological studies of GI endoscopy reported a 0.02% to 0.2% rate of perforation in diagnostic procedures.[53] In one series, there were no observed GI perforations in 9,000 endoscopic diagnostic procedures.[54] In a comparable study involving 10,049 patients, Daniel[2] reported a 0.02% incidence of bleeding associated with blind TEE probe insertion and no esophageal perforation. In a cohort of 7,200 patients undergoing TEE for heart surgery, perforation and bleeding rates of 0.01% and 0.03%, respectively, were recorded.[55] We experienced two esophageal perforations in a series of 8,000 patients examined in the operating room and ICU (Figure 2). When patients are conscious and sedated for TEE, perforations are evident from signs of subcutaneous emphysema, dyspnea, and pain. In contrast, under general anesthesia, the esophageal intubation is usually performed with ease, and the perforation goes unnoticed. Such occult iatrogenic esophageal lesions can result in mediastinitis, sepsis, and multisystem organ failure.[56–61] Esophageal perforation is associated with prolonged hospitalization and with a mortality rate of 20% to 30%[62] and, therefore, it must be suspected and diagnosed.[58] Diagnosis can be confirmed endoscopically or radiologically by computed tomography with contrast upper GI barium swallow studies and with chest radiographs

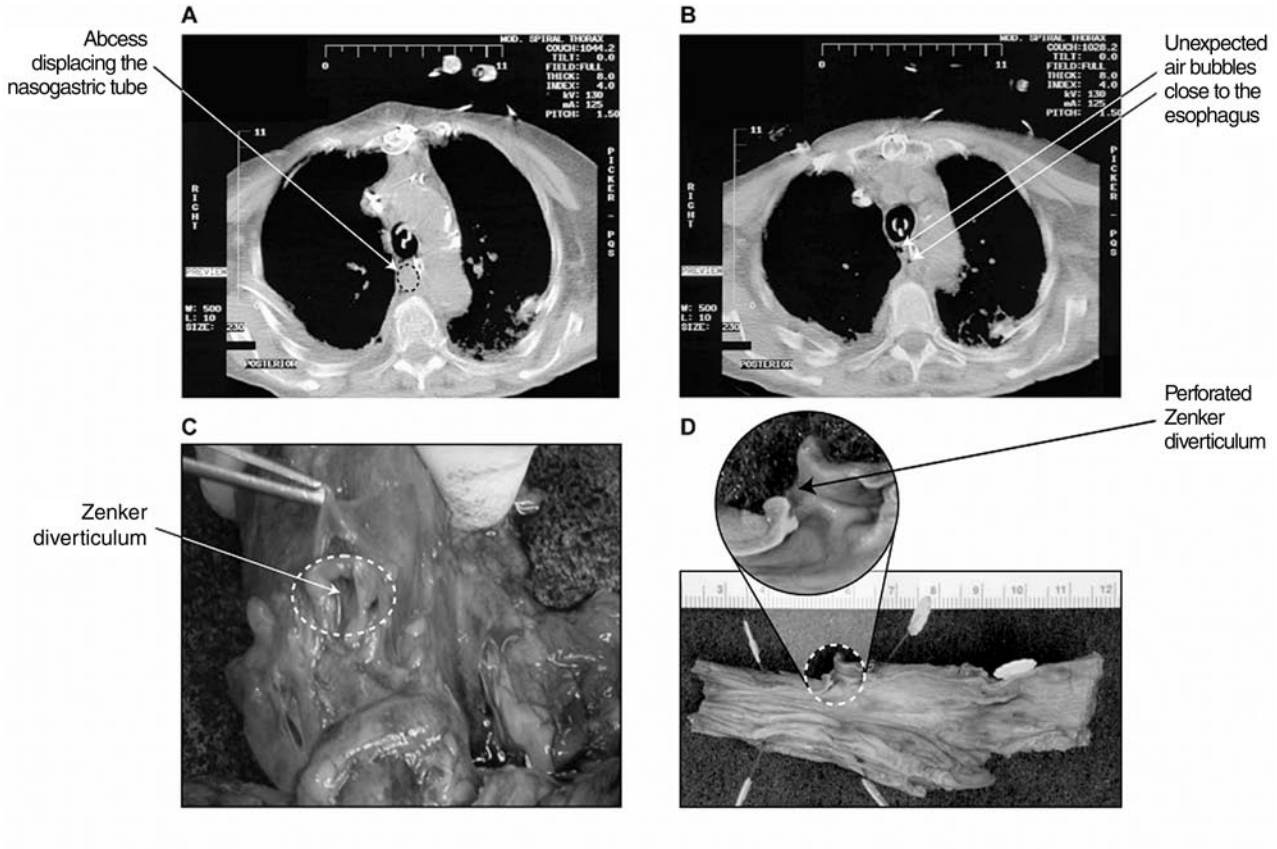

FIGURE 2 An 82-yr-old woman who died from septic shock after cardiac surgery. A) On computed tomography there was an abcess displacing the nasogastric tube. B) In addition there were some air bubbles close to the esophagus. C) From an external view, the autopsy showed the presence of an unexpected perforated Zenker diverticulum. D) Longitudunal internal view of the esophagus. The perforated Zenker diverticulum can be seen. It was perforated presumably by the transesophageal echocardiography probe either intraoperatively or postoperatively. Courtesy of Dr. Patricia Ugolini and Dr. Tack Ki Leung.

in the upright position. Radiological findings would include pneumothorax, pleural effusion, empyema, air/fluid levels, mediastinal shifts, and subcutaneous emphysema (Figure 2).

Bleeding of the gastroesophageal tract

Minor mucosal trauma during TEE can result in hematemesis or in blood-tinged sputum.[63] Early bleeding associated with TEE can be seen as spontaneous drainage upon probe removal or as blood flow during aspiration from the nasogastric tube. Several cases of Mallory-Weiss tear related to intraoperative TEE presented with bright red blood coming from the nasogastric tube.[43,50,64]

Late bleeding, that is, more than seven days after the procedure, is suggestive of an ulcerative process.[65] Risk factors that can precipitate upper GI bleeding due to TEE following cardiac surgery include a previous ulcerative process, vasoactive drug utilization, and absence of H_2 antagonism in the perioperative period.[66] Other factors, such as a long cardiac bypass period, urgent surgery, re-operation,[67] or aspirin use,[55] have also been implicated.

Anticoagulants may pose another potential problem. However, 107 individuals under full anticoagulation regimen (intravenous heparin or oral anticoagulation) for thrombotic disease or prosthetic valves displayed no increase in upper GI bleeding after TEE examination.[40] In contrast, hemothorax developed following esophageal abrasion by TEE in a patient who subsequently received thrombolytic therapy,[2] and post TEE supraglottic hematoma requiring tracheostomy occurred in a patient taking coumadin.[68] It can be surmised that, in patients receiving anticoagulants and undergoing non-visualized TEE, any minor trauma to the larynx, pharynx, or esophagus can result in serious complications.

Changes in esophageal lumen integrity

Intraoperative monitoring of ventricular function by TEE exposes the esophageal mucosa to ultrasound waves and to pressure for long periods. It is therefore important to consider whether this procedure results in esophageal injury. Endoscopic evaluation of the esophagus completed on children between four months and ten years of age immediately following intraoperative TEE disclosed abnormalities in 64% of the patients.[69] Abnormalities encountered included erythema (54%), edema (24%), hematoma (22%), mucosal erosion (14%), and petechiae (4%). Also, mild mucosal injury was documented more frequently in patients weighing less than 9 kg. No association of injury with probe length in the esophagus or with the duration of its use was found, and no long-term feeding or swallowing difficulties attributable to TEE manipulation were noted in the children who survived. In a similar study performed in nine children aged nine to 16 yr, endoscopy did not result in visible esophageal abnormalities.[70] It therefore seems that such lesions occur more frequently in smaller children.

No such studies have been reported, thus far, for adult subjects undergoing endoscopy during surgery. In an experimental study, however, TEE monitoring, for up to six hours during cardiac surgery in small monkeys and large dogs, did not lead to any macroscopic or microscopic esophageal changes or to thermal injury.[71]

Injury to solid organs and skin

Two rare cases of splenic laceration were reported after TEE monitoring during cardiac surgery.[72,73] Such laceration could be explained by deep insertion of the probe into the stomach for the purpose of transgastric imaging, placing it in close proximity to the spleen. Further advancement into the gastric cardia may place the probe in direct contact with the spleen,[74] thus producing traction on the splenic capsule[72] via the gastrosplenic ligament that contains the short gastric vessel. Withdrawal of the probe can relieve such traction and facilitate hemostasis.[74]

An incidental complication in a small infant occurred when the probe was left flexed in the stomach. It resulted in a prominent abdominal lump which was inadvertently lacerated during sternal incision.[75] These case reports emphasize the importance of maintaining an appropriate neutral probe position when not recording.

Dysphagia, recurrent laryngeal palsy, and tongue injuries

Perioperative TEE is an independent risk factor for dysphagia.[76] The mechanisms of such dysphagia may include local compression from the insertion maneuver or from the extent of probe insertion, both of which could affect the pharyngoesophageal tissue and/or the laryngeal nerve. Laryngeal nerve palsy occurs more commonly in female patients[77,78] because of a narrower laryngeal anatomy in females than in males.[77] Adult patients undergoing TEE display a 7.8-fold increase in postoperative dysphagia.[76] Dynamic swallowing studies have proven that four percent of adult patients exhibit mechanical swallowing dysfunction presenting as cough and dysphagia upon extubation after cardiac surgery.[79] Using barium cineradiography, dysphagia was observed in 7.9% of 126 patients undergoing intraoperative TEE during cardiac surgery *vs* 1.8% of 712 patients who did not undergo TEE.[76] Dysphagia was associated with pulmonary aspiration in 90% of cases, resulting in greater incidence of tracheotomies and a longer hospital stay. Associated risk factors include advanced age ($P < 0.001$), length of postoperative intubation ($P < 0.001$), and perioperative TEE examination ($P < 0.003$).[79]

In pediatric patients undergoing cardiac surgery, the incidence of dysphagia and left side vocal cord paralysis was 18% and 8%, respectively.[80] Associated risk factors were age of less than three years, tracheal intubation prior to surgery, operation for a left-sided obstructive lesion, and size of the probe in relation to patient's weight.[80] As in adults, dysphagia affects postoperative recovery and contributes to morbidity.

Patient positioning is another factor associated with dysphagia. Cucchiara[81] reported two cases of transient laryngeal dysfunction after TEE monitoring in neurosurgical patients who had been kept in a sitting position. Local effects of the probe, combined with an extreme flexion of the head in the sitting position, could contribute to and exacerbate local tissue stretching, resulting in dysphagia. Tongue swelling[82] and tongue necrosis[83] were reported after prolonged TEE placement, probably due to local compression by the TEE probe during perioperative monitoring.[84] Tongue injury is a rare but potentially lethal postoperative complication.

Probe tip buckling

Probe tip buckling should be suspected when imaging is difficult, when inappropriate resistance is felt during probe advancement, removal or mobilization, and when the control knobs are fixed.[81,85,86] When buckling is encountered, the probe should be advanced into the stomach where it can recover its neutral position prior to withdrawal. If the probe is pulled out in haste, its distal end can injure the esophagus (Figures 3 and 4).[87]

Such buckling is unlikely to occur in conscious

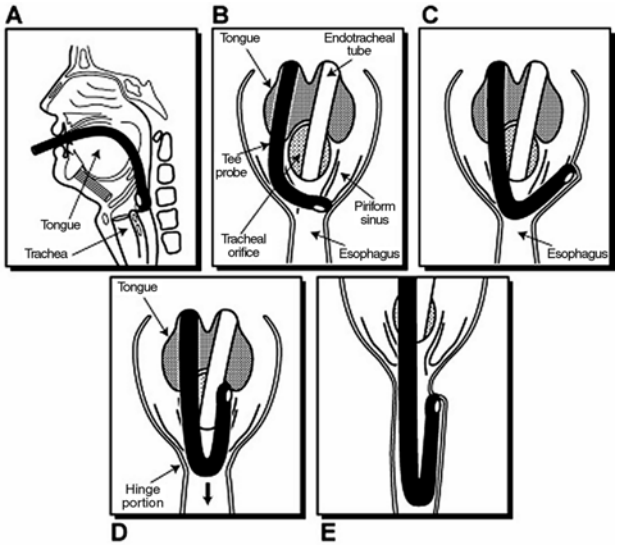

FIGURE 3 Difficult insertion of the transesophageal echocardiography (TEE) probe often results from a lateral insertion, as opposed to one from the midline (B-C). If excessive pushing occurs (D), the probe could be inserted in a flexed position resulting in buckling (E). With permission from Informa Healthcare (Denault *et al.* 2005).

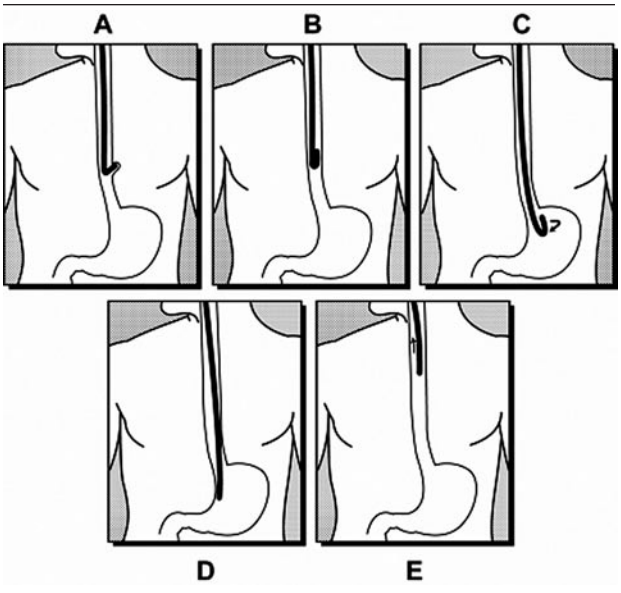

FIGURE 4 Buckling of the transesophageal echocardiography (TEE) probe can result in the inability to withdraw it from the esophagus. If this condition is suspected, pushing down the probe with distal extension will lead to successful removal of the probe. With permission from Informa Healthcare (Denault *et al.* 2005).

patients who can swallow or when laryngoscopy is undertaken. Chee *et al.*[40] noted only two cases of buckling in 901 conscious and sedated patients. Although a rare complication, it is a potentially dangerous technical malfunction. The risk factors associated with buckling are flaccidity of the probe tip, improper insertion technique, general anesthesia, and operator inexperience.[85,88] Inspection of the probe is mandatory, especially when using aging probes - after more than 300 examinations.[88] With time, steering wires controlling the flexion of the probe tip can become elongated, leading to insufficient stiffness required for esophageal intubation.

Other foreign bodies in the esophagus

The TEE probe in the esophagus sometimes shares the same space as other devices, such as a temperature probe, transesophageal stethoscope, nasogastric tube, and feeding tube. A broken nasal temperature probe associated with distal esophageal displacement has twice been reported.[89,90] An intact esophageal stethoscope was retrieved from a patient's stomach after TEE insertion during aortic valve replacement.[91]

II- Cardiovascular complications

Esophageal intubation is a stimulating maneuver that can induce vagal and sympathetic reflexes such as hypertension or hypotension, tachyarrhythmia or bradycardia, but it can also induce angina and myocardial ischemia.[40,92–95] In a multicentre European study,[2] cardiovascular complications during TEE occurred rarely (0.8%) and manifested as arrhythmias, non-sustained ventricular tachyarrhythmia (three cases), transient atrial fibrillation (three cases), and third degree block (one case). Cardiovascular complications increase with age, as > 70 *vs* < 50-yr-old patients have been reported to display systemic hypotension 3.5 times more frequently.[92] Sedation can be a contributing factor, as it can cause vasodilation and hypotension, especially in fasting patients, in those who have been receiving antihypertension or other drug treatment, and in those with other pre-existing conditions. Hypoxemia is also dangerous, as it can induce myocardial ischemia. A combination of sedation, catecholamines, and hypoxemia in patients suffering from reduced systolic function has been reported to precipitate heart failure[63] or fatal ventricular arrhythmia.[96] For these reasons, patients with coronary artery disease should be closely monitored during TEE, and they should receive prophylactic oxygen supplementation.

Under normal conditions, the contact pressure of the probe on the right atrium is less than 10 mmHg[51] and, therefore, if the patient has a mass in the right atrium, the chance of dislodging it during TEE is minimal. However, upon the initiation of TEE in conscious patients, retching (39% of patients) and coughing

commonly occur despite sedation and local anesthesia of the pharynx. The associated Valsalva maneuver increases intrathoracic, central venous, and pulmonary pressures, and its release results in an abrupt decrease of systemic pressure. The pressure variation by the Valsalva maneuver, used during echocardiographic examination to detect inter-atrial septal defects by its enhancement of right-to-left shunt, is thought also to cause the mobilization of any intracardiac material present. The extent of such embolization will depend on the hemodynamic fluctuations as well as on the size, density, and mobility of the mass.[97] It has been reported that large intrathoracic pressures and hemodynamic changes resulting from retching have produced fatal pulmonary embolization from a right atrial mass,[98,99] embolization of mitral vegetation and a left intracardiac thrombus resulting in stroke,[40,100] a myxoma embolus,[99] and progressive aortic dissection and cardiac tamponade.[101]

Pediatric patients may be more vulnerable to TEE, in that the esophageal probe can significantly compress vascular structures[69] such as a normally positioned[34] or aberrant right subclavian artery,[102,103] the descending aorta,[104,105] the innominate artery,[106] and the pulmonary venous confluence in an infant with total anomalous pulmonary venous return.[107–109] The hemodynamic effect of the TEE on cerebral perfusion pressure must also be reduced, especially in the presence of elevated intracranial pressure. In all of these situations, a strategy must be developed based on preexisting medical conditions.

III- Respiratory complications

As with endoscopic procedures, TEE examinations in sedated patients may be associated with a small, but significant, reduction of oxygen saturation. During endoscopy, the degree of desaturation is usually modest, about 4 to 6%, but desaturations as low as 51% have also been reported.[110,111] Whereas a mean fall in oxygen saturation reached 4.7% (ranging from 1% to 49%) in mildly sedated patients undergoing TEE, 18% of the patients exhibited significant hypoxemia, as defined by a persistent oxygen saturation below 90%.[112] Obesity increases the likelihood for oxygen desaturation during upper GI endoscopy and for aspiration during endoscopy,[113,114] although one study did not find any difference in transient oxygen desaturation between obese (mean body mass index 41 $kg \cdot m^{-2}$) and nonobese patients undergoing TEE examination.[115] When performed in the emergency department, TEE may cause further complications such as respiratory insufficiency and failure[116] (e.g., location-related examination complications). For these reasons, prophylactic oxygen supplementation should be administered to sedated conscious patients undergoing TEE. Such prophylaxis improves, but does not abolish, the oxygen desaturation, and, therefore, it is no substitute for diligent oxygen monitoring.

Although pulmonary complications during TEE in awake patients are rare, the potential difficulties include bronchospasm,[2,117] laryngospasm,[118] posterior pharyngeal wall hematoma,[41] supraglottic hematoma,[68] and subglottic stenosis.[119] Unilateral and bilateral pulmonary edema,[21,118,120] atelectasis,[121] and airway obstruction[122] can also be encountered. Prior oropharyngeal dysfunction and sedation enhance the risk for aspiration and call for brief endotracheal intubation under the care of an anesthesiologist.

An erroneous insertion of the esophageal tube in the trachea has been reported in four out of 1,500 examinations (0.27%) in ambulatory adults.[117] Symptomatically, such occurrences can be recognized by shortness of breath, stridor, and incessant coughing,[117] however, these symptoms can be masked by sedation. With accidental tracheal intubation, image quality is poor, the distinction of distal structures is difficult, and resistance to probe insertion is perceived at about 30–32 cm.[123–125] Also, the short axis of the aortic valve and the pulmonary artery bifurcation will not be seen at 30 cm,[124] and long axis views of the aortic arch, similar to those obtained from a suprasternal transducer position, will display poor distal resolution.[124,126]

Esophageal tube placement, movement, or removal may alter the placement of an endotracheal tube, particularly in the pediatric population, where extubation,[75,127] displacement into a large bronchus,[75,90] damage to the pilot cuff,[128] and a 1–2% incidence of severe airway obstruction have been reported.[75,129] Airway obstruction by a similar mechanism was also reported in two cases of adults undergoing repair of aortic aneurisms.[130] Even a compression by the esophageal probe of the pulmonary tree or the endotracheal tube can alter ventilation,[75,122,129,131–135] especially when congenital cardiovascular abnormalities, such as double aortic arch and truncus arteriosus, co-exist.[122] Decreased oxygen saturation, increased ventilation pressure, and modification of ventilation pattern of end-tidal CO_2 could signal such compression by the esophageal probe and should be assessed, not only under a static probe position,[136] but also dynamically, during the manipulation of the probe.

IV- Infections and prophylactic antibiotics

The risk of bacteremia associated with TEE must be considered, because bacteremia can lead to morbid infections, depending on a patient's immune status

and pre-existing conditions, and it can also lead to endocarditis. The most likely organisms are alpha-hemolytic streptococci and staphylococci, comprising, respectively, 55% and 25% of cases associated with native valve infection and 30% and 45% of cases associated with prosthetic valve infections.[137] The incidence of transient bacteremia varies greatly with the procedure.[138] Whereas the incidence of bacteremia is not altered by biopsies,[139] it ranges from 2% to 15% after diagnostic upper GI endoscopy.[139] Reports vary with regards to TEE, from stating a very low incidence of bacteremia, similar to anticipated blood culture contamination rates,[140,141] to declaring an incidence of 0% to 17%[119,142–144] in ambulatory and ICU patients.[139] Thus far, only two cases of bacterial endocarditis temporally related to TEE examination have been reported.[142,145] The single study in 24 patients reporting a 17%[143–146] incidence of transient bacteremia, but no endocarditis, concluded that bacteremia was common, and that antibiotic therapy should be routinely instituted during TEE.[143] However, the isolated organisms in that study were not sensitive to the antimicrobial prophylactic agents recommended by the American Heart Association (AHA).[143,144,147]

The use of antibiotic therapy during TEE is controversial. The AHA guidelines suggest such prophylaxis for patients who have prosthetic valves, previous endocarditis, complex cyanotic congenital heart disease, and surgically-constructed systemic pulmonary shunts or conduits. However, Eichelberger[148] reviewed antibiotic prophylaxis for prevention of endocarditis from 20 different centres during TEE in patients with pre-existing esophageal disease or poor oral and dental hygiene, and he concluded that there was no convincing evidence that antibiotic prophylaxis benefited this subgroup of patients. Further, a prospective study of 85 patients with prosthetic valves who underwent TEE disclosed that none showed evidence of bacterial endocarditis on follow-up,[149] and that positive blood cultures resulted from contamination. These authors concluded that the likelihood of bacteremia is very low, and that routine chemoprophylaxis in patients with prosthetic valves is not justified, except in cases of poor oral hygiene, prolonged or traumatic TEE procedures, or in subjects undergoing TEE in the first two months after valve replacement. Immunosuppression, an underlying cardiac pathology, an enduring bacteremia, and the type of organism involved might contribute to endocarditis and justify the use of antibiotics during TEE. Antibiotics are also essential for sepsis following intraoperative TEE associated with esophageal lesions, iatrogenic perforation, and mediastinitis, as discussed in a previous section.[56,58]

Clindamycin mouthwash has not been shown to reduce bacteremia after esophageal dilatation.[150] Whereas a latex cover sheath, adding a physical barrier, could be considered,[151] it may produce latex allergy. Its bulkiness can make probe insertion difficult and add discomfort, especially in awake patients, and its air tightness is not easily established.[151] As cleaning and disinfection are still needed to prevent probe contamination, it is not clear whether the cover sheath offers any advantage over standard measures for infection prevention.[63]

Although not yet demonstrated with TEE, bacterial and hepatitis B virus transfer via the probe has been documented in endoscopy.[152,153] The absence of a channel for aspiration or for instrumentation on the TEE probe, however, greatly reduces the risk of residual contamination. Mechanical cleaning, alone, removes organic and inorganic debris, reducing microbial contamination by 99%. The probability of contamination is further diminished with glutaraldehyde in the reprocessing protocol. Pseudomonas contamination of the lubricating jelly is another potential source of contamination. It was reported that a nosocomial outbreak of *Legionella pneumophila* was caused by a contaminated TEE probe.[154] Evidently, the strains isolated from three contaminated patients were identical to those obtained from the water used for rinsing the TEE probe. However, no endoscopy-transmitted HIV has been reported.[139] HIV appears to be very sensitive to disinfection practices, as a TEE probe contaminated with high HIV viral counts in body fluids displayed undetectable HIV by reverse transcriptase polymerase chain reaction after cleaning.[155] Ideally, the personnel and operator should be aware of the viral status of the patient, however, this is generally unknown.[156] The importance of vaccination and self-protection (goggles, gloves, gowns) must be emphasized, as a possible contamination from accidental biting, fluid, and droplets is unpredictable. Herpetic infection of a finger, resulting from contaminated oral secretions and herpetic conjunctivitis acquired during endoscopy from saliva spray, occurs frequently enough to deserve the sobriquet "endoscopist eye".

V- Medication-related complications

Sedation

Sedation improves patient tolerance during TEE examination. It reduces coughing, vomiting, and pain. Repeated episodes of retching, not only decrease patient comfort and willingness to pursue the procedure, but also prevent proper cardiac imaging. Anesthetic and medical associations have developed criteria and guidelines for non-anesthesiologists to follow when administering sedation in conscious patients.[157]

Various sedative agents can be used, such as benzodiazepines or propofol, in combination with small doses of short-acting narcotics. Adverse drug reactions, such as respiratory depression, hypotension, paradoxical agitation, and allergic response, must be recognized and treated promptly. Dosage should be adjusted to age, weight, and pre-existing medical condition. Elderly or disabled patients and those suffering from sleep apnea are overly sensitive to sedation and analgesia and should be carefully monitored. In most elderly patients, minimal sedation is required or, in up to one third, local anesthesia is sufficient.[158] The results of successful sedation for TEE should include anxiolysis, amnesia, and cooperation. The benzodiazepine antagonist, flumazenil, can reverse the adverse effects of midazolam which occur in 6% of patients with cardiac pathology undergoing TEE.[159]

Local anesthetic medications

Sedation combined with local anesthesia reduces the hemodynamic effects associated with esophageal intubation and probe manipulation.[118] The local anesthetic drug is rapidly absorbed when applied on mucous surfaces, and if adequate local anesthesia and suppression of the gag reflex cannot be obtained, a superior laryngeal nerve block can be performed.[16] Allergic reactions to local anesthetics are rare. Central intoxication by lidocaine occurs in 0.6 to 1.3% of cases and is expressed by marked lethargy, disorientation, confusion and drowsiness. An underlying liver dysfunction, congestive heart failure, or a concomitant use of lidocaine analogs may predispose patients to such toxic side effects.[160]

Methemoglobinemia

Methemoglobin is hemoglobin A in which iron exists in its ferric form (trivalent state) rather than its normal ferrous state (divalent state). Oxygen-carrying capacity is greatly reduced, as the ferric form cannot bind oxygen. Methemoglobin also shifts the oxygen dissociation curve to the left, lowering the ability of hemoglobin to release oxygen to tissues. Methemoglobin is continuously formed in erythrocytes and is reduced to deoxyhemoglobin by nicotinamide adenine dinucleotide-dependent methemoglobin reductase enzyme. Congenital absence of the methemoglobin reductase enzyme may predispose patients to the development of methemoglobinemia. Topical anesthetics, such as prilocaine, lidocaine, and benzocaine, cause oxidation of hemoglobin to methemoglobin. When the rate of such oxidation exceeds that of methemoglobin reduction, methemoglobin accumulates, leading to methemoglobinemia. Whereas the physiological level of methemoglobin is below 2%,[161] many cases of methemoglobinemia have been reported in outpatient TEE examination settings.[162–172]

The presence of methemoglobinemia is suggested by central cyanosis, despite adequate arterial oxygen partial pressure, and by low measured hemoglobin saturation unresponsive to oxygen therapy. Dyspnea with mild associated mental confusion can also be observed as well as dizziness, frank coma, and even death. Cooximetry is necessary to diagnose methemoglobinemia, as methemoglobin is a dark pigment that causes blood to appear chocolate in color. Treatment of cyanosis due to methemoglobinemia is achieved by intravenous infusion of 1 to 2 $mg \cdot kg^{-1}$ of methylene blue. The total dose given should not exceed $7 mg \cdot kg^{-1}$. An overdose can cause dyspnea, hemolysis, and chest pain.[173] Methylene blue acts as a co-factor to restore hemoglobin's oxygen-carrying capacity. Congenital methemoglobin or glucose-6-dehydrogenase deficiency should be suspected if no improvement is seen after injection of methylene blue. In such cases, a consultation with hematology is mandatory, and exchange transfusion or dialysis should be considered.

Anticholinergic agents

Anticholinergic agents are used to reduce salivation and to enhance the action of local analgesic agents. Glycopyrrolate exerts milder tachycardic effects than does atropine, but it can cause tachyarrythmia, premature ventricular contractions, and atrial fibrillation, perhaps augmented by the stress of the procedure.[174] Other side effects sometimes occur,[175] and these agents should be used with particular caution in patients with glaucoma or urinary retention.[156] Unlike glycopyrrolate, a synthetic antimuscarinic agent, atropine and scopolamine can cause excitement or delirium, because both cross the blood-brain barrier.[176]

VI- Miscellaneous complications

Glutaraldehyde and nucleotide probe contamination

A disruption of the integrity of the protective probe sheath can create a lumen between the probe's external sheath and internal core. This lumen can fill with fluids and contaminants, such as glutaraldehyde, that can then be ingested. Improper cleaning of intact probes can lead to chemical burns from residual Cidex® (orthophtaldehyde)[177] or to contamination by radionucleotides.[178]

Latex aerosolization

Powdered latex gloves used for maintenance of TEE machines can produce aerosolized latex particles that can cause latex-induced anaphylaxis in vulnerable patients.[179]

Location-related complications

Performing TEE in the emergency department has a higher complication rate than in other clinical settings that average 1% to 3% (Table II). A retrospective review of TEE examinations in emergency departments demonstrated a 12.6% incidence of complications, including death, respiratory insufficiency or failure, hypotension, emesis, agitation, and cardiac dysrythmia.[116] Compared to patients with medical or elective conditions, trauma patients experience a higher incidence of complications, because they often present with marginal hemodynamic and respiratory conditions and with multiple co-existing injuries (such as unstable C-spine damage). Considered as subjects with full stomachs, such trauma patients also have a significant risk of aspiration, especially when combined with altered levels of consciousness. Before proceeding with TEE examination in that population, it is mandatory to protect the airway by endotracheal intubation. Whereas TEE is a versatile tool for diagnosing and treating severely ill patients, lack of space in the ICU suite and difficult passage of the probe render this procedure problematic.[180,181]

Transnasal esophageal echocardiography

Whereas transnasal probe introduction has recently been suggested, this procedure has significant shortcomings, such as a failure rate of 10% to 16%,[182–184] nasopharyngeal bleeding in 0 to 31%,[182–184] and difficult management requiring nasal tamponade. It is wrong to believe that the transnasal approach protects against esophageal perforation. In addition, image quality and its interpretation appear to be less precise with this approach, thus arguing against nasal intubation as an indicated approach.

TABLE III Contraindications to TEE

1. Absolute contraindications *
Lack of informed consent
Unwilling and uncooperative patient
Lack of expertise in intubation for TEE
Esophageal obstruction (cancer, stricture)
Gastric volvulus
Active upper gastrointestinal bleeding
Perforated viscus (known or suspected)
Full stomach
Suspected neck injury
2. Relative contraindications
2.1 Known esophageal pathology
Esophageal varices without bleeding
Esophageal diverticulum
Transesophageal fistula
Esophagitis/inflammatory process
Gastric herniation
Scleroderma
Carcinoma
Penetrating or blunt thoracic esophageal trauma
History of previous esophageal surgery
Esophagectomy
Fundal-plication gastric surgery
2.2 Cervical abnormalities
Severe cervical arthritis/osteophytes/severe cervical spondylosis
Neck surgery/radiotherapy in the cervical region
Severe oropharyngeal distortion
2.3 Miscellaneous
Prior mediastinal irradiation
Coagulopathy
Nasal intubation
History of nasal/nose surgery
Septal deviation

*Although these contraindications are absolute, the risk/benefit ratio should be evaluated for every patient, and alternative approaches (limited to upper and mid-esophageal view or epiaortic view) should be sought. TEE = transesophageal echocardiography.

VII-Local effects of ultrasound waves on surrounding tissues

Theoretically, a powerful ultrasound beam can cause a vibration of small gas-filled structures (i.e., cavitation), thus producing hemorrhage or hemolysis. Whereas such effects have been reported in experiments conducted in animals,[185–187] none has been shown in humans.[188] Furthermore, a powerful ultrasound beam can produce excessive tissue heat and damage and can be used in therapeutic indications such as during lithotripsy. However, when used at low intensity, typically at 5 MHz for TEE procedures, ultrasound has yet to display any harmful effects.[189,190] Therefore, the World Federation for Ultrasound in Medicine and Biology and common sense dictate that the operator know the precise power output and intensity of the ultrasound instrument being used. The operator must balance the benefits against the risks of its use and minimize the patient's exposure to ultrasound.

VIII-Echocardiographer expertise

Because of the complexity of TEE and its associated risks, the American Society of Echocardiography, the Society of Cardiovascular Anesthesiologists, and the European Society of Cardiology have strict requirements for optimal initial training of echocardiographers and for their ongoing advancement of expertise in performing this procedure.[191–194]

IX-Prevention of transesophageal echocardiography-related complications

Prior to undertaking TEE, the procedure must be explained to the patient, risks *vs* benefits stated, and

an informed consent obtained. A complete physical examination and careful questioning on medical history, allergies, and medications are essential. The examination must include an evaluation of oral hygiene and loose teeth (for preventive antibiotic treatment), an assessment of neck mobility, stability, and arthritic changes, and an analysis of the airways. Swallowing problems, a possible indicator of orogastric narrowing, may be a possible contraindication to TEE probe insertion[195] and should prompt consultation with gastroenterology and radiological barium swallowing studies. Past GI surgery, recent endoscopic procedure, and chest wall radiotherapy may hint at esophageal abnormalities, and a chest *x-ray* should be performed to rule out pathologies, such as hiatus hernia (Figure 5). Sometimes, even such precautions do not prevent esophageal laceration during TEE.[196]

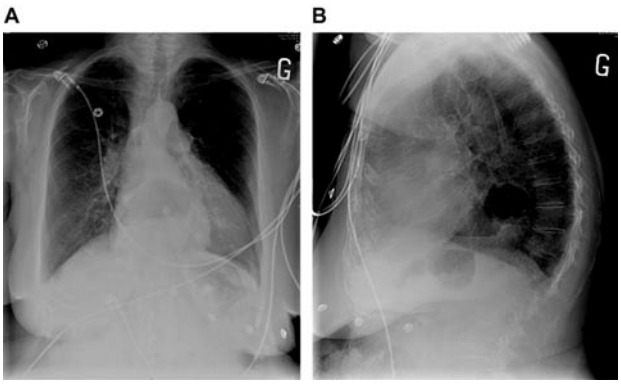

FIGURE 5 Chest radiograph from a 72-yr-old woman with an esophageal hernia. Air shadows can be seen in the middle of the chest (A) and behind the left atriun on the lateral view (B). (Courtesy of Dr. Patricia Ugolini).

It is essential to properly store the probe holder and the probe, itself, and to protect its distal part.[197–200] Prior to TEE examination, the probe must be inspected for both mechanical dysfunction and for damage to the flexible outer sheath that can collect contaminated fluid causing electrical or thermal injuries,[39] potentially resulting in arrhythmia and death[201] or to a steel wire damage of the esophageal mucosa.[202] The control system must be unlocked at all times to ensure probe flexibility and to prevent esophageal tear by rigid tubes.[85]

Monitoring vital signs at baseline and throughout TEE is essential. Blood pressure, electrocardiogram, and pulse oximetry must be monitored throughout the intervention. Oxygen supplementation and venous access should be established for sedation or to manage any complications. Equipment should include a suction device and resuscitation cart, and supporting personnel should be present to alleviate some of the burden placed on the echocardiographer.[203]

The TEE examination under conscious sedation is very different from that under general anesthesia. Whereas rapid anesthetic induction in emergency situations is followed by orotracheal intubation, in an elective procedure performed in an awake, fasting patient, the patient is placed in a left lateral decubitus position to minimize the risk of aspiration, and a suction device is placed close at hand and ready for use.[63] Sedation and local anesthesia will improve the success of esophageal intubation. Dental fixtures must be removed before intubation, and a bite guard should be placed, especially in awake procedures and in patients with full dentures, as it protects the instrument and the operator's fingers. The TEE probe should be lubricated, in an unlocked control-wheel position, and its passage never forced. The probe must be kept central to the tongue and guided in a fluid movement without excessive force in a posterior manner against the posterior pharyngeal wall. The awake patient is asked to swallow during probe insertion. This closes the vocal cords bringing the larynx up and forward under the posterior aspect of the tongue and opening the cricopharyngeal muscle. Under general anesthesia, a jaw thrust maneuver can help overcome resistance felt in the hypopharynx region when the probe is in contact with the epiglottis or with other glottic structures. Probe placement under direct laryngoscopy may reduce the risk of lesions associated with numerous blind attempts. The screen monitor should be active to confirm the proper location of the probe in the esophagus.[124] Careful insertion of 40 to 50 cm from the incisors is advocated.[204] Resistance to probe insertion within the esophagus can result from esophageal abnormalities, as discussed earlier. When the probe is introduced under general anesthesia, the entire oropharyngeal musculature is relaxed. This could predispose the probe to being pushed into a mucosal fold and ultimately to buckle or to cause a lesion. Such a risk is reduced in awake subjects who can collaborate by swallowing the probe and indicating the presence of pain or discomfort during probe manipulation. Under general anesthesia, patients do not experience intolerance, retching, or gag reflex. The endotracheal tube and its cuff provide some protection against aspiration. Any nasogastric or feeding tube or temperature probe should be removed to avoid potential kinking, knotting, or gastric migration and loss, as well as to prevent interference during image acquisition. Special care must be taken during cardiac surgery, as the TEE probe stays much longer than during a diagnostic examination, and as anticoagulation during the

TABLE IV Patient evaluation and surveillance

Written consent
Careful medical history:
- Dysphagia to solids or liquids
- Esophageal web, varices, upper gastrointestinal bleeding, peptic ulcer disease, gastroesophageal reflux, hiatal hernia
- Previous gastric, esophageal or neck surgery
- Cervical arthrosis, paresthesia
- Radiation therapy
- Bleeding disorder
- Use of anti-acid, salicylates, anticoagulation or anti-platelet agents
- Allergy
Examination
- Teeth, oral and dental hygiene, throat for neck deviation and mobility
- Airway evaluation as in endotracheal intubation
Endocarditis prophylaxis for high-risk patients
- Prosthetic valves, previous endocarditis, complex cyanotic congenital heart disease, and surgically-constructed systemic pulmonary shunts or conduits
- Poor oral hygiene
- Esophageal disease
Fasting for 6 hr before the procedure
Prevention of aspiration in specific cases
Surveillance and monitoring of patients during and after the procedure
Presence of trained personnel for monitoring and technical support
Treatment of complications
Quality-controlled verification, follow-up of patient satisfaction and complaints

TABLE V Summary of key questions before, during, and after performing transesophageal echocardiography (TEE)

Before:
1-What is the indication for TEE?
2-Are there any contraindications for TEE? (esophageal disease and cervical spine injury)
3-Rule of the 6 "A"s
-Accepted - informed consent signed and procedure explained
-Airway (including dental) and ventilation evaluation for potential difficulties
-Absence of a full stomach
-Allergies?
-Antibiotics required?
-Anticoagulation?
During and after:
A: will the airway be compromised?
B: will ventilation be compromised?
C: is there a risk of hemodynamic compromise during the procedure?
D: diagnosis of any new complications after the procedure?
E: examination of the probe after procedure

bypass period, the hypothermic state, and blood flow reduction can render the mucosa more susceptible to pressure necrosis and ischemia. Cardiopulmonary events account for most of the complications during TEE and endoscopic procedures in sedated patients. Continuous monitoring and vigilance are required to anticipate problems and make prompt corrections (Table IV).

After the procedure, the patient should remain under observation until the effects of the sedation and the local anesthetic agent dissipate. A trained assistant must continue monitoring the patient during this transition period prior to discharge. Eating and drinking are allowed once the effects of local anesthetic have dissipated. Driving after the procedure is prohibited because of sedation during the examination. Furthermore, the patient should be discharged to the care of a responsible escort. Table V summarizes a practical approach in the use of TEE in our Centre.

Limitations

Although we tried to carefully review the most relevant and up-to-date literature on the topic of complications related to TEE, we identified at least one article[205] that mentions complications related to gastroscopy, without being the central theme. It is possible that our search strategy overlooked some articles; however, we have tried to provide clinicians using TEE with a practical presentation of the most important complications in relation to this technique.

Conclusions

Compared to regular transthoracic echocardiography, in which bone and lung tissue can interfere with cardiac imaging, TEE allows greater probe proximity to posterior cardiac structures, thus greatly improving the imaging of cardiac anatomy and function. Whereas this echocardiographic approach is more invasive and can be associated with complications, experts in this technique should be aware of the nature of such complications, to minimize risk factors and to take the necessary precautions to prevent their occurrence.

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