

RESEARCH

Is transnasal TEE imaging a viable alternative to conventional TEE during structural cardiac interventions to avoid general anaesthesia? A pilot comparison study of image quality

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Abstract

Aim: The role of transoesophageal echocardiography in cardiac interventional structural procedures is well established and appreciated. However, the need for general anaesthesia (GA) throughout the procedure remains a controversial issue. The aim of the present study is to assess the feasibility and imaging quality of using a transnasal microrobe that allows the usage of conscious sedation in patients who undergo cardiac structural interventional procedures without missing the benefits, guidance and navigation of conventional trans-procedural TEE.

Methods: We analysed the trans-procedural images of 24 consecutive patients who underwent TAVI, TMVI or ASD/PFO closure, using a transnasal 2D microprobe (PHILIPS) and then we compared them with images taken by using a conventional 3D TEE probe (PHILIPS). In particular, we compared the imaging quality of the two probes regarding: (1) The anatomy, visualisation of valvular calcification and transvalvular colour Doppler of the aortic and mitral valve; (2) the imaging quality of PFO, ASD and interatrial communication colour flow; (3) the imaging of left ventricle systolic function and pericardial space and (4) transgastric imaging.

Results: All images were graded with a scale from 5 to 1. The average grade of imaging quality in the mitral valve was: anatomy, 4.3; calcification, 3.8; colour Doppler, 4.2. The average grade of imaging quality in the aortic valve was: anatomy, 4.3; calcification, 3.7; colour Doppler, 4.3. The average grade of imaging quality in PFO/ASD was 4.3. The average grade of imaging quality in LV/pericardial space was 4.2. The average grade of imaging quality in transgastric imaging was 4.1.

Conclusion: These results suggest that transnasal TEE can provide good anatomical image quality of relevant cardiac structures during cardiac structural interventions and this may facilitate these procedures being performed during conscious sedation without having to lose TEE guidance.

Key Words

- 2D transoesophageal echocardiography
- transcatheter aortic valve replacement

Introduction

Over the last 20 years, there has been a huge increase in the number of cardiac percutaneous interventions, offering treatments not only to patients with coronary

disease, but also to those with cardiac valve disease or cardiac structural abnormalities. The crucial role of transoesophageal echocardiography (TEE) in cardiac



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interventional structural procedures is now well established, as it provides detailed visualisation of cardiac anatomy, haemodynamics and guidance, for optimal success of catheter-based interventions.

However, there is still an ongoing debate whether these procedures should be taken under general anaesthesia (GE) or conscious sedation (CS). Conventional TEE cannot be performed without offering GE during cardiac interventions, as the patient must be intubated whilst manipulating the TEE probe for guiding the procedure. Therefore, there has been a drive to perform cardiac interventions, especially valve implantations, without any echo guidance, under only conscious sedation and local anaesthesia, to avoid any possible GA complications and side effects. This has been proved feasible, however with the compromises of safety (late detection of procedure-related complications), efficiency (more radiation, as longer procedural time is necessary for adjusting the final position of the valves or devices) and in outcome success (as there was no echo intra-procedure outcome assessment and re-adjustment if necessary) (1). The dilemma has been addressed differently in various cardiology centres, based mainly on individual experience and preference.

Aim of the study

Based on current data mentioned above, we performed this study to investigate whether transnasal TEE imaging could be a viable alternative to conventional TEE during structural cardiac interventions, as it combines the benefits of the conventional TEE guidance and navigation, without the potential side effects and possible complications of GA. The study was approved by the Ethics Research Committee of King's College Hospital (KCH Ref No: 10-H0718-13).

Methods

Transnasal TEE was performed using a thin TEE microprobe, originally designed for paediatric use, with extended operating frequency range of 3–8 MHz and physical dimensions of:

- (a) Tip: 7.5 × 5.5 × 18.5 mm (width, height, length).
- (b) Shaft diameter: 5.2 mm.
- (c) Length (gastroscope section): 85 cm.

The microprobe can perform multiplane angulation from 0 to 180 degrees in 2D imaging and is equipped

with steerable PW Doppler, CW Doppler, colour Doppler, M-mode and harmonic imaging (Philips S8-3t sector array multiplane microTEE ultrasound transducer for the iE33).

The aim of our study was to compare the feasibility of using a TEE microprobe in cardiac interventions under conscious sedation, with regard to patient tolerance and oxygenation and comparison with image quality obtained from images acquired with a conventional TEE probe. We analysed the trans-procedural images of 24 patients who underwent transfemoral aortic valve implantation (TAVI), transfemoral mitral valve implantation (TMVI) or atrial septal defect (ASD) or patent foramen ovale (PFO) closure, using a transnasal 2D microprobe (PHILIPS) and then we compared them with images taken by using a conventional 3D TEE probe (PHILIPS).

Informed written consent has been obtained from each patient after full explanation of the purpose and nature of all procedures.

We compared images of the mitral valve in 24 cases, of the aortic valve in 19 cases, of the interatrial septum in 12 patients, of left ventricular function and the pericardial space in 21 cases, and transgastric imaging in 10 cases.

All patients underwent pre-procedural assessment with TEE, using a conventional 3D TEE PHILIPS XE72 TEE probe on a PHILIPS i33 Ultrasound machine, two to four weeks prior to the procedural date, to assess cardiac anatomy, to acquire detailed measurements of the structures involved and plan the procedure. Subsequently, most of the patients (20) underwent a catheter-based procedure, using the previously described transnasal microprobe for procedural guidance. In the rest of them (4), the procedure was done under conventional TEE but a transnasal TEE was performed at the same time to get comparison images. The patient's position was either supine or left lateral, but this did not seem to affect the image quality when comparing two studies of conventional TEE on the same patient before and during procedure and therefore it was assumed that the different position did not affect the image quality in the transnasal TEE too. The targeted structures were different among all study patients but we compared only the same structures on the same patients. Technically, the sector width and sector frequency were the same in all of our studies.

When transnasal TEE was used in the procedure, a full study was performed in the very early stages, under an identical TEE study protocol with conventional echo procedures. The microprobe was introduced through the nose, using a small-calibre (5 mm) nasopharyngeal

Table 1 Imaging quality grades.

Structure	Mitral valve	Aortic valve	PFO/ASD	LV/pericardial space	Transgastric imaging
Average grade of imaging quality	Anatomy: 4.3 Calcification: 3.8 Colour Doppler: 4.2	Anatomy: 4.3 Calcification: 3.7 Colour Doppler: 4.3	4.3	4.2	4.1
Number of patients	N=24	N=19	N=12	N=21	N=10
P value	<0.05	<0.05	<0.05	<0.05	<0.05

sheath. An oxygen mask, equipped with a port for the TEE probe was applied to the patients, as well as all necessary preparations for CS. All images were taken by the same operator and were reviewed and graded independently.

The pre-assessment studies were performed under conscious sedation, using midazolam 1–5 mg IV after obtaining written informed consent. On the other hand the intraprocedural nasal TEE studies involved anaesthesia and sedation. Patients were carefully selected for suitability and compliance with TAVI procedure performed under sedation. An explanation of the nasal TEE was given to patients before embarking upon the procedure. In addition, patients were fasted and all drugs and equipment for conversion to general anaesthesia were immediately available. Peripheral intravenous access and intra-arterial monitoring were secured. Midazolam in 0.5–1 mg aliquots was administered as required for anxiolysis. The patient was asked to sniff through each nostril (whilst blocking the other) in order to determine which would offer least resistance to the passage of the probe. The chosen nostril and nasopharynx was then anaesthetised with a combined local anaesthetic

and vasoconstrictor preparation (lidocaine 5% and phenylephrine 0.5% spray). The oropharynx was anaesthetised with intraoral lidocaine 1% spray. Low-dose remifentanyl (target-controlled infusion) was also administered, whilst taking care to maintain verbal contact with the patient. A modified face mask was used to deliver oxygen whilst allowing passage of the probe into the nose, and capnography was monitored through the mask. Once sufficiently numb the nasal TOE probe was lubricated and inserted very gently as tolerated. After having been successfully advanced into the oesophagus, care was taken to warn the patient if the probe needed to be moved. Continuous ECG recording, O₂ saturation and respiratory rate monitoring were documented during all procedures. All patients tolerated the procedure well, without any reported incident of discomfort or pain and the probe was never withdrawn.

Specifically, we compared the imaging quality of the two probes regarding:

1. The anatomy, visualisation of valvular calcification and quality of transvalvular colour Doppler of the aortic and mitral valve.
2. The imaging quality of PFO, ASD and any interatrial communication by colour flow Doppler.
3. The imaging of left ventricle systolic function and pericardial space.
4. Transgastric imaging quality.

All images were graded with a scale from 5 to 1, with:

5. Excellent quality: Indistinguishable from conventional 3D TEE probe.
4. Very good: Almost similar to conventional 3D TOE probe.
3. Good: Inferior to conventional 3D TOE probe, but sufficient and safe imaging quality.
2. Medium quality: Only gross pathology can be seen.
1. Poor quality: Unacceptable imaging.

Then, we averaged the grades of each image taken by the transnasal probe, having as a reference point the optimal possible image taken by using a conventional probe and then we compared them by using Student's *t*-test.

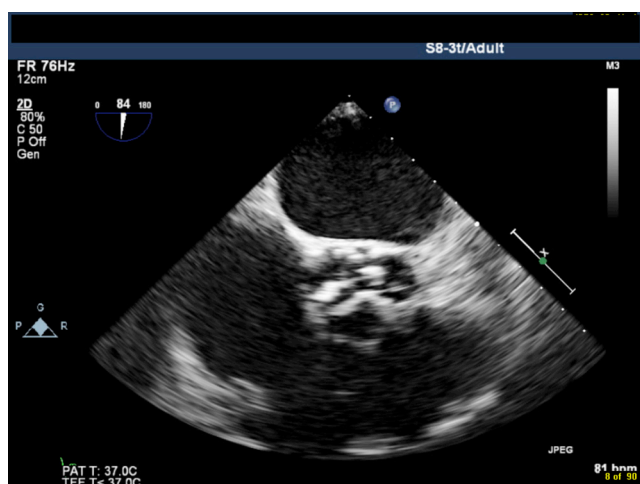


Figure 1

Aortic valve short axis view demonstrating the imaging of valve calcification by using transnasal TEE. The aortic valve anatomy clarity was graded with 4/5 and the aortic valve calcification clarity with 3/5 in this image.

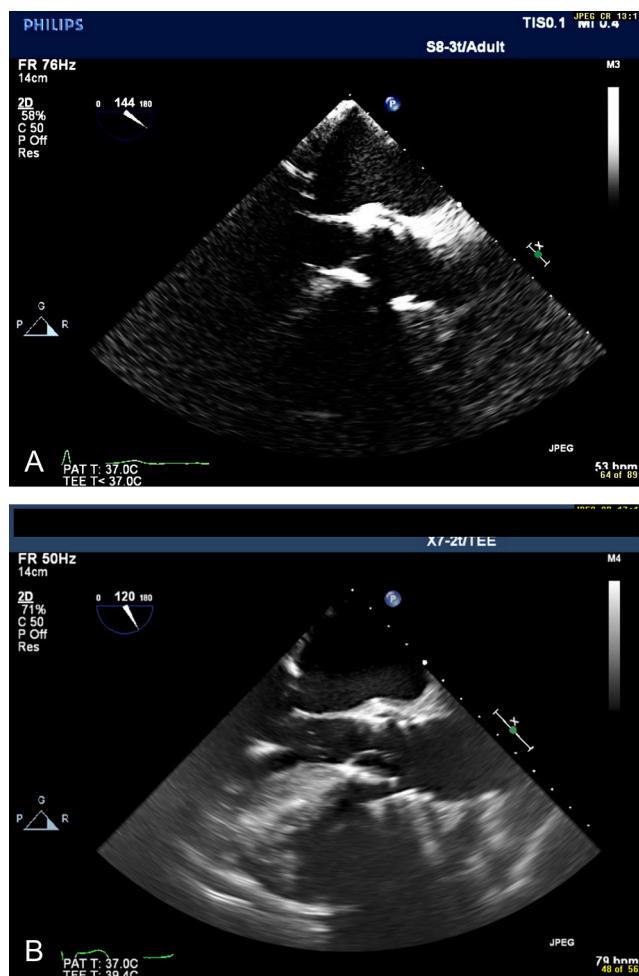


Figure 2
(A and B) Aortic valve imaging by using conventional and transnasal TEE on the same patient.

Results

The results were the following, presented as the average grade from 5 to 1 (Table 1).

The clarity of structure calcification with transnasal TEE was inferior to conventional TEE in the cases of limited extent of calcification (Fig 1), on structures that retain their original anatomical shape. However, when the calcification was not extended, it was demonstrated with almost similar quality (Fig 2).

Nevertheless, the anatomical boundaries and the colour Doppler evaluation of relevant intracardiac structures were seen with almost similar quality (Fig 3). Both mitral valve opening and closure and leaflet motion, during valve implantation procedures, had imaging quality almost undistinguishable from conventional TEE.

Valve positioning and post-implantation assessment were accurate; nevertheless the addition of 3D imaging

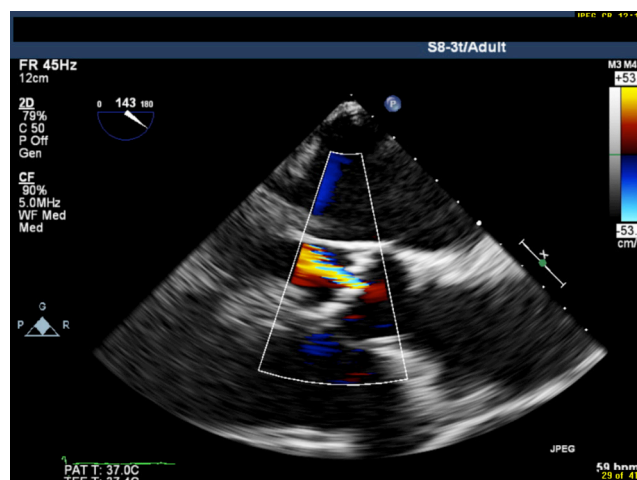


Figure 3
Long axis view with colour Doppler with transnasal TEE that was graded with 5/5.

would provide with even more information. The same applies for ASD/PFO closure procedures where the size assessment, device navigation and post-operative assessment achieved were almost of non-inferior imaging quality but with slightly longer acquisition times due to more complicated probe manipulation (Fig 4).

Transgastric imaging proved very challenging and this is due to difficulty in maintaining contact with the stomach wall (Fig 5). More advanced operator skills are required for controlling the thinner and more flexible probe; however, familiarisation with the microprobe behaviour shortens the imaging time required. In general from the operator point of view, the transnasal TEE was not more uncomfortable than the conventional one.

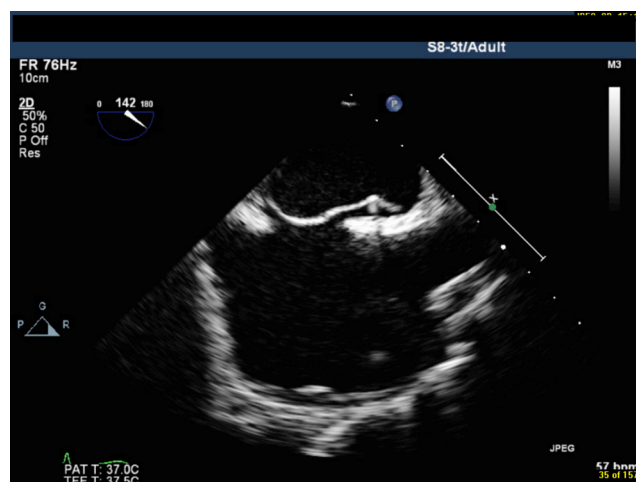


Figure 4
PFO assessment and measurements during PFO closure procedure using transnasal TEE (grade 4/5).

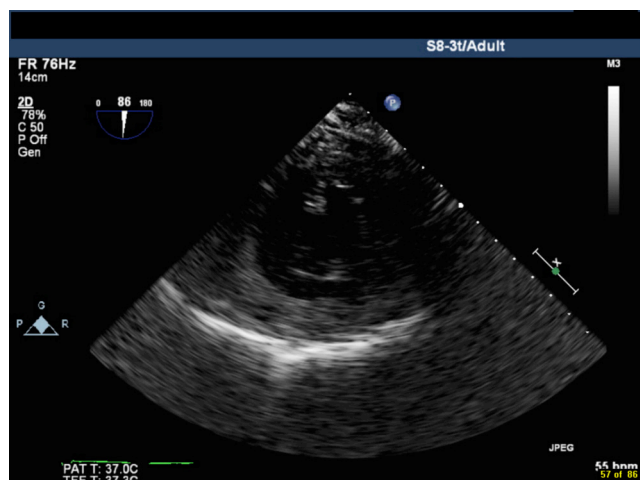


Figure 5
Transgastric imaging by using transnasal TEE (grade 3/5-good imaging quality but inferior to conventional TEE).

In two cases there were difficulties with patient ventilation and O_2 saturations that required airway manoeuvres, and in one case the procedure was abandoned before valve implantation. However, these side effects are exclusively related to the CS strategy and not to the microprobe use.

Finally, the acquisition time was similar by using either technique. In some patients it was proved slightly longer when using the transnasal probe due to limited familiarisation with the probe manipulation.

Discussion

TEE guidance has been established as a mandatory component of the vast majority of structural cardiac interventions, because of procedural guidance, evaluation of procedural outcomes, reduced fluoroscopy exposure, reduced contrast usage and the prompt detection of any procedure-related complication (2). As conventional periprocedural TEE demands GA, structural interventions can take place only with CS if no conventional TEE is performed. Therefore, the question has changed into CS without TEE vs GA with TEE as the only reason for performing transnasal TEE is actually to maintain echo guidance despite applying CS. However, there are centres performing conventional TEE with CS but this is generally avoided.

The proposed benefits of CS can be summarized by the reduced procedure time, shorter intensive care unit (ICU) length of stay, reduced need for intraprocedural

vasopressor support and the potential to perform the procedure without the direct presence of an anaesthetist for cost-saving reasons (3). Additionally, periprocedural vasopressor therapy was consistently lower in the CS patients in most trials. This is very important as pre-existing hypovolaemia in combination with the vasodilatory effect of anaesthetic agents may lead to significant hypotension in patients undergoing GA and thus explain the increased requirement for vasopressor therapy in this group. Vasopressors were used in only up to 26% of patients under CS, in the study of Balanika *et al.* regarding anaesthetic management during TAVI procedures (3). Time saving is also frequently proposed as an advantage of a CS strategy too.

However, CS can potentially cause hypotonia of the hypopharyngeal muscles (4) and increased incidence of obstructive sleep apnoea, as has been described in up to 75% of elderly patients, from Ancoli-Israel *et al.* (5). All sedatives and opioid analgesics affect respiration to a certain degree and by further reducing the pharyngeal muscle tone this may result in mild anaesthesia-induced hypercapnia, which has been shown to impair the coordination between swallowing and respiration and may therefore elevate the risk of aspiration (6).

With regard to the O_2 saturation, Mayr *et al.* showed cumulative cerebral desaturation was comparable between CS and GA in patients undergoing TAVI procedure. Neurocognitive function did not change within and between groups (7). Minor adverse events like bradypnoea and the need for airway manoeuvres or bag-mask-ventilation were more frequently observed in CS patients (8). This was also observed, in a lesser degree in our study as mentioned above.

Remarkably, Maas *et al.* reviewed ten studies, including 5919 patients, regarding general or local anaesthesia in TAVI procedures again and showed that neither mortality nor the incidence of major adverse cardiac and cerebrovascular events after TAVI is affected by the choice of local and regional anaesthesia, with or without CS, or GA (1).

Finally, Brecker *et al.* investigated the Impact of Anesthesia Type on Outcomes of Transcatheter Aortic Valve Implantation (from the Multicenter ADVANCE Study) with no statistically significant difference between the non-GA and GA groups in all-cause mortality (25.4% vs 23.9%, $P=0.78$), cardiovascular mortality (16.4% vs 16.6%, $P=0.92$), or stroke (5.2% vs 6.9%, $P=0.57$) through 2-year follow-up (9). Major vascular complications were more common in the non-GA group. Total hospital stay was

similar between the 2 groups. However, conversion from non-GA to GA occurred in 13 patients (5.3%) because of procedural complications in 9 patients and discomfort or restlessness in 4 patients. It must be highlighted here though that most procedural complications were related to valve positioning or vascular issues and that two of the 13 converted patients died during the procedure (9). The latter demonstrates the importance of echo guidance in the avoidance of such serious complications and its contribution to successful procedures.

Taking into consideration all of the aforementioned studies, there is no clear prevalence of any of the two strategies, and cardiac centres tend to adopt the strategy they have more familiarisation and experience with. However, there is no doubt that TEE guidance is of major importance and this has been a major compromise for centres using CS in structural interventions.

Implementation of CS with echo guidance using intracardiac echocardiography (ICE) has been recently described. Kadakia *et al.* reported the use of 3D-ICE in TAVI procedures, trying to overcome not only the limitation of TEE in the need for general anaesthesia and endotracheal intubation, but additionally to eliminate obscured fluoroscopic views during valve positioning and deployment. They found that assessment of valve positioning and aortic insufficiency were comparable to that provided by conventional TEE imaging, though there were several important limitations and proposed ICE-guided TAVI as an important alternative to TEE for TAVI imaging guidance might allow for less-intensive sedation or anaesthesia (10).

Moreover, Masson *et al.* investigated whether ICE can be used in LAA closure procedures. Procedural success was achieved in 36 of 37 patients (97%). In all cases, ICE imaging yielded good LAA and surrounding structure visualisation and adequate procedural guidance, however three major procedural or in-hospital complications occurred. Follow-up TEE documented the absence of any residual peri-device leak in all but 1 (29 of 30) case, and they came to the conclusion that LAA occlusion with the Amplatzer Cardiac Plug using ICE guidance from the left atrium is feasible, reproducible and safe (11).

The major disadvantage for the wider application of ICE in cardiac structural interventional procedures seems to be the cost, as a new catheter is necessary for each procedure and that raises the procedural cost significantly. The transnasal TEE using a microprobe is now being introduced as an alternative, offering all of the above-mentioned advantages of the ICE approach but with no cost limitation. As with conventional TEE, only

one probe is needed for all cases offering non-inferior imaging for both GA and CS patients. However, currently a 3D microprobe is not available and this is a potential disadvantage compared to conventional TEE and must be weighed up against the advantages of having 2D TEE available during structural interventions performed under CS. It must be highlighted that this is a preliminary study that does not allow to assess the real clinical impact of this technique.

To recap, transnasal TEE seems to be a promising alternative compared to the existing imaging techniques during interventional procedures, given that the operator is familiarized with the microprobe and is highly skilled and experienced. The rest of the limitations of this newer technique could be summarized in the further image quality improvement and the current absence of 3D data, but this is subject to the development of newer more advanced technology.

Conclusion

These results suggest that transnasal TEE can provide good anatomical image quality of relevant cardiac structures during cardiac structural interventions and this may facilitate these procedures being performed during conscious sedation without having to lose TEE guidance.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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References

- 1 Maas EH, Pieters BM, Van de Velde M & Rex S 2016 General or local anesthesia for TAVI? A systematic review of the literature and meta-analysis. *Current Pharmaceutical Design* **22** 1868–1878. (doi:10.2174/1381612822666151208121825)
- 2 Pislaru SV, Michelena HI & Mankad SV 2014 Interventional echocardiography. *Progress in Cardiovascular Diseases* **57** 32–46. (doi:10.1016/j.pcad.2014.05.009)
- 3 Balanika M, Smyrli A, Samanidis G, Spargias K, Stavridis G, Karavolias G, Khoury M, Voudris V & Lacoumenta S 2014 Anesthetic management of patients undergoing transcatheter aortic valve implantation. *Journal of Cardiothoracic and Vascular Anesthesia* **28** 285–289. (doi:10.1053/j.jvca.2013.07.010)
- 4 Mayr NP, Michel J, Bleiziffer S, Tassani P & Martin K 2015 Sedation or general anesthesia for transcatheter aortic valve implantation (TAVI). *Journal of Thoracic Disease* **7** 1518–1526. (doi:10.3978/j.issn.2072-1439.2015.08.21)

- 5 Ancoli-Israel S & Coy T 1994 Are breathing disturbances in elderly equivalent to sleep apnea syndrome? *Sleep* **17** (Supplement 8) 77–83. (doi:10.1093/sleep/17.suppl_8.S77)
- 6 Hoch CC, Reynolds CF 3rd, Monk TH, Buysse DJ, Yeager AL, Houck PR & Kupfer DJ 1990 Comparison of sleep-disordered breathing among healthy elderly in the seventh, eighth, and ninth decades of life. *Sleep* **13** 502–511.
- 7 D'Angelo OM, Diaz-Gil D, Nunn D, Simons JC, Gianatasio C, Mueller N, Meyer MJ, Pierce E, Rosow C & Eikermann M 2014 Anesthesia and increased hypercarbic drive impair the coordination between breathing and swallowing. *Anesthesiology* **121** 1175–1183. (doi:10.1097/aln.0000000000000462)
- 8 Mayr NP, Hapfelmeier A, Martin K, Kurz A, van der Starre P, Babik B, Mazzitelli D, Lange R, Wiesner G & Tassani-Prell P 2016 Comparison of sedation and general anaesthesia for transcatheter aortic valve implantation on cerebral oxygen saturation and neurocognitive outcome. *British Journal of Anaesthesia* **116** 90–99. (doi:10.1093/bja/aev294)
- 9 Brecker SJ, Bleiziffer S, Bosmans J, Gerckens U, Tamburino C, Wenaweser P, Linke A & ADVANCE Study Investigators 2016 Impact of anesthesia type on outcomes of transcatheter aortic valve implantation (from the Multicenter ADVANCE Study). *American Journal of Cardiology* **117** 1332–1338. (doi:10.1016/j.amjcard.2016.01.027)
- 10 Kadakia MB, Silvestry FE & Herrmann HC 2015 Intracardiac echocardiography-guided transcatheter aortic valve replacement. *Catheterization and Cardiovascular Interventions* **85** 497–501. (doi:10.1002/ccd.25409)
- 11 Masson JB, Kouz R, Riahi M, Nguyen Thanh HK, Potvin J, Naim C, Salem R & Raymond JM 2015 Transcatheter left atrial appendage closure using intracardiac echocardiographic guidance from the left atrium. *Canadian Journal of Cardiology* **31** 1497.e7–1497.e14. (doi:10.1016/j.cjca.2015.04.031)

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