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INSTITUTO DE CIÊNCIAS BIOMÉDICAS ABEL SALAZAR
UNIVERSIDADE DO PORTO

Intraoperative transesophageal echocardiography: review and evolution

Mariana Perez da Costa de Albuquerque Duque

DISSERTAÇÃO DE MESTRADO INTEGRADO EM **MEDICINA**

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ORIENTADOR: Prof. Dr. Humberto José da Silva Machado

Abstract

Background Presently, transesophageal echocardiography (TEE) is routinely used in adult cardiac surgery with increase frequency as well as in perioperative hemodynamic monitoring during noncardiac surgeries.
Objectives The aim of this analysis was to understand the evolution of the use of intraoperative TEE (iTEE) both in cardiac and noncardiac surgeries showing popular and challenging approaches in its use, and as a secondary goal, comprehend the patterns to achieve technic competency.
Methods A literature review was carried out identifying relevant clinical studies published in last six years through popular search engines using the keywords listed below.
Results The quick acquisition of cardiac anatomy and function data give iTEE an importance in cardiac procedures that is undeniable, permitting refine diagnosis, detect unsuspected pathology, adjust both anesthetic and surgical plans and evaluate immediate surgical outcomes. Although, its use is less established in noncardiac surgery, the latest guidelines give an increasingly role for TEE in monitoring patients in high instable risk surgeries or in patients with several comorbidities that can compromise the hemodynamic status even in lower risk surgeries. iTEE is a multifaceted technical expertise and demonstration of competence is usually accomplished by successful conclusion of a training program and passing an examination. Restrictive factors to its widely use seemed to be availability of trained operators and equipment.
Conclusions iTEE should be used as an auxiliary tool to have more comprehensive understanding of the patient's cardiovascular physiology and manage a most adequate anesthetic approach and surgical intervention. Meanwhile, it is advisable to have large systematic studies supporting its powerful value in both cardiac and noncardiac surgeries. Suitably, it is desirable an international adoption of TEE basic skills within anesthesia practice. Education is the most influential instrument to contribute in shifting the anesthesiology community's standpoint of TEE use in daily clinical practice.

Keywords
Transesophageal echocardiography, intraoperative, cardiac surgery, non-cardiac surgery

Resumo alargado

Introdução

A monitorização cardiovascular durante um procedimento cirúrgico pode ser um desafio para o anestesista, especialmente se o risco de instabilidade hemodinâmica do doente for alto.

A introdução da ecocardiografia transesofágica (ETE) no bloco operatório representa um desenvolvimento na gestão de tais doentes, mesmo aqueles que não estavam em risco, mas que sofreram uma consequência ou complicação durante o procedimento. Esta técnica permite uma imagem direta e rápida do coração e grandes vasos com elevada resolução espacial devido à proximidade entre sondas que emitem ultra-sons de alta frequência e as estruturas supracitadas.

A monitorização invasiva da pressão arterial é essencial na gestão intra-operatória, mas a precisão das medições periféricas em comparação com as centrais tem sido questionada. O papel desta ferramenta tornou-se difícil de definir. Atualmente, faz parte de um processo de tomada de decisão, fornecendo informações determinantes que podem alterar o procedimento cirúrgico, o plano anestésico, confirmar a suspeita diagnóstica, auxiliar no posicionamento de dispositivos intravasculares e expandir-se para *follow-ups* adicionais. O uso do ecocardiograma transesofágico intraoperatório (ETEi) pode ser dividido com base no tipo de procedimento, sendo ele cirúrgico ou por via endovascular (Kothavale *et al.* 2009, Gouveia *et al.* 2011, Hahn *et al.* 2013, Montealegre-Gallegos and Mahmood 2014).

Presentemente, o ETEi é utilizado rotineiramente em doentes adultos submetidos a cirurgia cardíaca para fins de diagnóstico bem como para monitorização hemodinâmica perioperatória. No que diz respeito à idade do paciente, ETEi já ultrapassou esta barreira, sendo que durante uma cirurgia cardíaca pediátrica, é já um procedimento de rotina com as suas próprias indicações (Gouveia *et al.* 2011, Hahn *et al.* 2013, Starczewska *et al*. 2014).

Contudo, o uso em cirurgia não-cardíaca está menos estabelecido, sendo que as últimas normas da Sociedade Americana de Anestesistas e da Sociedade de Anestesistas Cardiovasculares concordam que o ETEi deveria ser usado em cirurgia não-cardíaca. São indicações para a sua utilização as seguintes situações: a) quando os doentes apresentam patologia cardiovascular conhecida ou suspeita, que possa resultar em compromisso hemodinâmico, pulmonar ou neurológico, b) sempre que estejam disponíveis os recursos necessários, especialmente em condições que o risco de vida e instabilidade esteja presente, apesar da correta abordagem terapêutica (Orban *et al.* 2013, Vitulano *et al*. 2015).

Objetivos

O objetivo desta análise foi a compreender a evolução do uso do ETE intraoperatório, tanto em cirurgia cardíaca como não cardíaca, mostrando abordagens desafiadoras no seu uso e, como objetivo secundário, compreender os padrões para alcançar a respetiva competência técnica.

Métodos

Uma revisão da literatura foi realizada a identificação de estudos clínicos relevantes publicados nos últimos seis anos através de motores de busca *PubMed* e *Google scholar* usando as palavras-chave listadas no final do resumo.

Resultados

A rápida aquisição de dados de anatomia e da função cardíaca dá-lhe uma importância em procedimentos cardíacos inegável, permitindo refinar o diagnóstico, detetar patologia insuspeita, ajustar o plano anestésico e cirúrgico e avaliar no imediato os resultados.

Embora a sua utilização em cirurgia não-cardíaca esteja menos estabelecida, as diretrizes mais recentes dão um papel cada vez mais importante ao ETE na monitorização de doentes em cirurgias de alto risco ou em doentes com várias comorbilidades que podem comprometer a estabilidade hemodinâmica mesmo em cirurgias de risco menor (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Hahn *et al.* 2013).

O ETEi é uma perícia técnica multifacetada sendo a sua demonstração de competência efetivada após conclusão bem sucedida de um programa de treino e aprovação num exame. São fatores restritivos à sua ampla utilização a disponibilidade de operadores treinados e equipamentos.

Discussão

Cirurgia cardíaca e aórtica

ETE não só é uma mais-valia que influencia a tomada de decisão anestésica e cirúrgica mas também custo-efetiva. Canty *et al.* (2015) descobriram que a ecocardiografia transesofágica pode predizer e monitorizar a distensão do ventrículo esquerdo, dado comum neste tipo de cirurgia.

Talvez um dos mais importantes contributos do ETEi a 3-dimensões (3D) no bloco operatório é a avaliação do ventrículo esquerdo (VE). A precisão do volume ventricular esquerdo e da medida da sua função (fração de ejeção) compara-se aos valores obtidos por meio da ressonância magnética cardíaca. À medida que a tecnologia progride, estes parâmetros tornam-se facilmente analisados durante a cirurgia, como também a deteção precoce de anormalidades do movimento da parede miocárdica, permitindo avaliar a condição cardíaca do doente (Ferreira *et al.* 2013, Reeves 2013).

O valor da massa do VE é comummente usado como preditor da morbilidade e mortalidade associadas à patologia cardiovascular. No decorrer de uma cirurgia cardíaca, a massa ventricular esquerda pode ser calculada através da multiplicação do volume ventricular esquerdo pelo seu peso com o ETE, possibilitando o diagnóstico de patologia do VE, como a cardiomiopatia hipertrófica (Ferreira *et al.* 2013). Isto é extremamente útil na cirurgia não-eletiva quando certas anormalidades cardíacas são descobertas. Em adição, a avaliação do diâmetro e área do VE em diástole podem ser usados para diagnosticar hipovolémia e consequentemente monitorizar fluidoterapia.

A avaliação da função ventricular direita deve ser feita por rotina em todos os doentes cardíacos cirúrgicos, uma vez que se apresenta como um preditor na morbilidade e mortalidade, particularmente na presença de hipotensão (Reeves 2013). Enquanto que os exames de eleição para avaliar a função do ventrículo direito continuam a ser a ressonância magnética cardíaca e a ventriculografia com radionuclídeos, o ETE parece ser a ferramenta mais adaptada ao contexto do bloco operatório. A tecnologia 3D permite a avaliação completa do volume do ventrículo direito, da anatomia, geometria e fração de ejeção. Com esta capacidade, é esperado que a imagem e função do ventrículo direito se tornem parte do exame extensivo do ETE, enfatizando a influência desta avaliação (Ferreira *et al.* 2013, Ramakrishna *et al.* 2016). Apesar do ETEi não ser o exame de eleição no diagnóstico intra-operatório de embolia pulmonar, os achados ecocardiográficos consistentes com embolia pulmonar aguda são precisamente a disfunção do ventrículo direito e anormalidades atípicas da parede livre do miocárdio ventricular direito (Reeves 2013).

O ETE 3D em tempo real pode avaliar com precisão a localização, o tamanho e os anexos das massas intracardíacas assim como defeitos septais auriculares e ventriculares, simplificando o planeamento cirúrgico (Hanna *et al.* 2010, Saric *et al.* 2010, Vegas and Meineri 2010). Os mixomas são os tumores cardíacos mais comuns e podem surgir em qualquer uma das quatro câmaras, em número superior na aurícula esquerda. Atentando à relação entre a aurícula esquerda e a válvula mitral (VM) é possível predizer algum grau de disfunção valvular quando o tamanho do tumor é grande o suficiente ou quando a sua localização abrange o aparelho valvular mitral (Teng *et al.* 2015). Yamagushi and Koide (2015) relataram um caso de uma regurgitação mitral mascarada que apenas foi detetada num segundo ETEi numa cirurgia de resseção de um tumor, tendo no entanto, auxiliado na tomada de decisão para o procedimento valvular apropriado. Os autores reforçaram ainda a ideia que o ETE deve ser usado para avaliar a presença de disfunção valvular mitral antes e depois do procedimento de resseção de tumores intracardíacos. Em adição, Dharmalingam and Sahajanandan (2014) demonstraram uma alteração na abordagem cirúrgica num caso de um mixoma auricular direito, destacando a importância do ETEi na caracterização das massas cardíacas. O ETE realizado no intraoperatório dá informações específicas sobre a extensão e dependências dos mixomas. Entre as massas valvulares, as mais conhecidas são vegetações da endocardite infecciosa em que o ETE é recomendado para casos cirúrgicos, refinando a abordagem cirúrgica (Methangkool *et al.* 2014, Yong *et al*. 2015).

Cirurgia da válvula mitral

A reparação cirúrgica da VM está a ser progressivamente implantada no tratamento da regurgitação mitral severa, constituindo uma opção excelente de tratamento com baixo risco e durabilidade alta. Uma das mais fortes indicações do ETEi é a avaliação da VM durante o procedimento de reparação ou substituição. O aparelho valvular mitral, a função e os segmentos patológicos são avaliados bem como outros fatores de risco que podem ser apreciados para reparação cirúrgica; a correta colocação das cânulas utilizadas para circulação extracorporal na cirurgia minimamente invasiva também é auxiliada por esta ferramenta (Ender and Sgouropoulou 2013, Sidebotham *et al.* 2014). Quando uma abordagem não-sistemática é usada, como no período intraoperatório, existem evidências de uma boa correlação entre o observado por ETE e os achados cirúrgicos (Peterson *et al.* 2003).

Considerando a avaliação pós-operatória, ETE 3D mostrou simplificar a visualização de toda a estrutura da nova válvula artificial e da sua função. A imagem qualitativa do ETE 3D é mais adequada para visualizar a anatomia e localização das patologias, enquanto que a análise quantitativa a 2 dimensões (2D) é mais precisa para medidas e quantificar a gravidade. Igualmente, o ETE 3D Doppler pode mostrar o local certo da regurgitação mitral paravalvular, útil para encerramento percutâneo de fendas com correção cirúrgica imediata. É necessário excluir também estenose mitral, avaliar a função ventricular e rever a possibilidade de outras complicações vasculares do procedimento cirúrgico (Ender and Sgouropoulou 2013, Ferreira *et al.* 2013, Hien *et al*. 2014, Maslow *et al.* 2014, Shiota 2014, Sidebotham *et al.* 2014, Maslow 2015, Maslow 2015, Ramakrishna *et al.* 2016). Mesmo algumas variáveis ecocardiográficas foram recentemente identificadas como preditoras independentes de risco de falha cirúrgica (Lubos *et al*. 2014).

À medida que a cirurgia minimamente invasiva e as técnicas *off-pump* na reparação/substituição da VM se tornam bem conhecidas, o papel do ETE acaba por ser essencial para a monitorização neste tipo de tratamentos menos invasivos, já que simplifica a cirurgia, melhora os resultados e é altamente compensador (Ender and Sgouropoulou 2013). O papel consolidado do anestesista cardíaco no bloco operatório é inegável e a sua competência deve ser exemplar para concretizar grandes resultados na nova era da cirurgia cardíaca.

Cirurgia não-cardíaca

As questões encaradas no bloco operatório durante uma cirurgia não-cardíaca são bastante distintas. O ETE pode ser uma instrumento importante para os doentes com comorbilidades significativas ou se é antecipada instabilidade hemodinâmica ou se esta ocorre no intraoperatório (Rebel *et al.* 2012).

A instabilidade hemodinâmica e as mudanças rápidas no volume são complicações graves. O impacto da visualização direta das estruturas cardíacas tem o potencial de fornecer rapidamente informações importantes sobre a função cardiovascular, relevantes para a gestão hemodinâmica. Em procedimentos cirúrgicos complexos, como o transplante de fígado, devido à manipulação cirúrgica ou perda sanguínea, a probabilidade de instabilidade hemodinâmica é alta e assim, o ETEi pode acrescentar informação importante para a gestão do doente.

Além disso, hipotensão e arritmias estão frequentemente associadas com a instabilidade hemodinâmica. A primeira pode ser devido a insuficiência cardíaca, hipovolémia ou resistência periférica reduzida (RPR). Mesmo na perda aguda de sangue, a RPR pode existir juntamente com sinais de hipovolémia. Consequentemente, as avaliações do débito e da pré-carga cardíacos são fatores importantes no exame intraoperatório. Muitas destas variáveis demonstram boa correlação quando comparado com as técnicas mais invasivas; mesmo no caso da detecção de alterações hemodinâmicas agudas, o ETE é superior ao cateter da artéria pulmonar (Galhardo 2010).

Para mostrar o uso original e astuto deste dispositivo em cirurgia não-cardíaca, em 2014 foi descrito um caso raro de uma massa externa (fígado transplantado) que causou compressão cardíaca, resultando em vários episódios de taquicardia supraventricular, imediatamente após o transplante. Esta compressão miocárdica sintomática pelo fígado foi diagnosticada e confirmada através de imagens em tempo real de ETE com um desenlace bem sucedido (Stoll, Hand et al. 2015). Mesmo na cirurgia obstétrica, Cho *et al.* (2012) relataram um caso raro de instabilidade hemodinâmica abrupta numa cirurgia de histerectomia vaginal, na qual o ETE foi realizado para diagnóstico e um trombo auricular direito foi identificado.

Na neurocirurgia, a posição sentada foi um progresso importante na melhoria do campo cirúrgico, no entanto, os riscos não são desprezíveis. Recentemente foi demonstrado que o ETE tem uma excelente sensibilidade no intraoperatório para detetar ar na aurícula direita, uma complicação temida, através de dados em tempo real com quantificação visual e, por isso, é possível dizer que a posição sentada pode ser relativamente segura quando a monitorização com ETE é usada (Ganslandt *et al*. 2013, Reeves 2013).

Ensino e competências

O ecocardiograma é uma técnica multifacetada e o fator restritivo é a disponibilidade de operadores treinados e equipamento. Dobbs *et al.* (2014) realizaram uma sondagem eletrónica internacional a fim de compreender melhor a prática global de ETEi em cirurgia cardíaca em adultos. Os resultados corroboram que as principais barreiras para o uso do ETEi em 27 países foram a falta de recursos (equipamentos e pessoal). No entanto, o ETE usa-se mais frequentemente e por pessoal mais qualificado do que em estudos anteriores. Estes resultados são um apelo para a criação de programas de formação básica em ETE entre os internos anestesistas, bem como entre os assistentes não-qualificados, permitindo uma nova geração de médicos que dominem a técnica e sabem como tirar proveito na prática clínica do seu potencial.

A obtenção de competências em ETE geralmente é conseguida pela conclusão bem sucedida de um curso e pela aprovação no exame final (Barber and Fletcher 2014).

Recomenda-se seguir a atual via de acreditação existente se o objetivo é adquirir competência em ETE. Na cirurgia cardíaca, o nível avançado de ecocardiografia é necessário, com aptidões de diagnóstico completo e domínio nos modos Doppler e imagem 3D. No entanto, é possível a um interno que passa um ano num estágio de anestesia cardíaca desenvolver as habilidades necessárias para realizar um exame ETE completo se o equipamento estiver acessível. A formação perioperatória básica é principalmente dedicada à monitorização intraoperatória, ao passo que a formação avançada tem como objetivo diagnósticos específicos (Sharma and Fletcher 2014, Peng *et al.* 2015).

A Sociedade Europeia de Ecocardiografia em conjunto com a Associação Europeia de Anestesistas Cardíacos oferece uma certificação através de uma avaliação em dois componentes, um exame de escolha múltipla e a apresentação de uma compilação de 125 exames realizados pessoalmente no período de um ano. A partir desses exames, 15 casos são selecionados aleatoriamente e posteriormente classificados por examinadores externos. A manutenção da certificação requer pelo menos 50 ETE por ano (25 a certificação básica) e educação médica continuada.

As exigências para nível avançado ou diretor não são especificadas neste consenso, mas nas orientações da ASA e SCA para competência em ecocardiografia perioperatória exigem 150 e 300 ETEs realizados, nos níveis avançado e diretor, respetivamente (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Hahn *et al.* 2013, Reeves 2013, Peng *et al.* 2015).

O progresso tecnológico permitiu a concepção de simuladores de ecocardiografia; vários estudos têm demonstrado um papel importante no futuro da formação em ecocardiografia sem acesso de rotina ao ambiente operatório, demonstrando resultados superiores na aprendizagem. Estas plataformas são especialmente importantes para o iniciado, uma vez que melhora a experiência, a velocidade de aprendizagem e o conforto com o ETE (Jerath *et al.* 2011, Damp *et al.* 2013, Vegas *et al.* 2013, Mitchell *et al.* 2014, Arntfield *et al.* 2015).

Conclusões

As informações fornecidas pela ecocardiografia transesofágica podem ser muito valiosas no tempo intra-operatório permitindo ou restabelecendo a estabilidade hemodinâmica. Deve ser usado como ferramenta auxiliar na compreensão abrangente da fisiologia cardiovascular do doente, possibilitando a gestão de uma intervenção cirúrgica adequada. Com baixo risco, dependendo em conjunto de um operador qualificado experiente e da anatomia e comorbilidades do doente, é um importante instrumento perioperatório que pode melhorar o resultado cirúrgico.

Grandes estudos sistemáticos são recomendados para medir o seu papel na cirurgia não-cardíaca, especialmente desde que tem sido promissor no acompanhamento dos doentes na cirurgia de transplante de fígado. Por conseguinte, é desejável a adopção de competências básicas em ecocardiografia transesofágica intraoperatória dentro do ensino da anestesia em todo o mundo.

O valor crucial do ETEi prende-se com a forma de como a informação obtida é interpretada e utilizada para a gestão do paciente cirúrgico. Os riscos e benefícios devem ser sempre ponderados. Cabe às equipas anestésica e cirúrgica agir em conjunto a fim de analisar rapidamente os dados e intervir em conformidade com o melhor interesse do doente.

Uma vez perito e hábil, o anestesista amplifica a sua posição na medicina perioperatória, contribuindo com evidências clínicas vitais para o procedimento anestésico-cirúrgico.

Palavras-chave

Ecocardiografia transesofágica, intraoperatório, cirurgia cardíaca, cirurgia não-cardíaca

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List of abbreviations

2D - Two-dimensional
3D - Three-dimensional
AD - Aortic Dissection
AoV - Aortic Valve
AR - Aortic Regurgitation
ASA - American Society of Anesthesiologists
ASD - Atrial Septal Defect
ASE - American Society of Echocardiography
CHD - Congenital Heart Disease
cMRI - Cardiac Magnetic Resonance Image
CPB - Cardiopulmonary Bypass
iTEE - Intraoperative Transesophageal Echocardiography
LA - Left Atrium
LT - Liver Transplantation
LV - Left Ventricle
MELD - Model for End-Stage Liver Disease
MV - Mitral Valve
OR - Operating Room
PE - Pulmonary Embolism
RPR - Reduced Peripheral Resistance
RT - Real Time
SCA - Society of Cardiovascular Anesthesiologists
TEE - Transesophageal Echocardiography
TF - Tetralogy of Fallot
US - Ultrasound
VSD - Ventricular Septal Defect

Introduction

Cardiovascular monitoring during a surgical procedure can be a challenge for the anaesthesiologist, especially if the patient has high probability of hemodynamic instability.

The introduction of transesophageal echocardiography (TEE) in the operating room (OR) represents a development of the management of such patients, even in those who were not at risk, but suffered from a consequence or complication through the procedure. This technique allows a direct and fast image of the heart and great vessels by using high frequency ultrasound probes improving the spacial resolution due to the proximity between the transducer and the heart.

Invasive blood pressure monitoring is essential in intraoperative management, but the accuracy of peripheral readings in comparison to central measurements has been questioned. The role of this intraoperative management tool became difficult to define, it is now part of the decision-making process, providing determinant information that can change the surgical procedure and anaesthetic plan, confirm a suspected diagnosis, assist in positioning of intravascular devices and may extend far for additional follow-up. Intraprocedural TEE can be divided in surgical-based procedure and catheter-based procedure (Kothavale *et al.* 2009, Gouveia *et al.* 2011, Hahn *et al*. 2013, Montealegre-Gallegos and Mahmood 2014).

Currently, TEE is used in adult cardiac surgery with increase frequency for diagnosis purposes as well as perioperative hemodynamic monitoring. Intraoperative TEE (iTEE) is beyond barriers in what concerns of patient's age. Today during a pediatric cardiac surgery, TEE is a routine procedure with its own indications too.

However, its use during noncardiac surgeries is less established, the latest guidelines of the American Society of Anesthesiologists (ASA) and Society of Cardiovascular Anesthesiologists (SCA) agreed that TEE should be used in noncardiac surgery when patients have known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary or neurologic compromise, and in conditions of unexplained life-threatening circulatory instability persists despite corrective therapy; all if experts and equipment are available (Gouveia *et al.* 2011, Hahn *et al.* 2013, Starczewska *et al*. 2014). Yet, the use of iTEE in noncardiac surgery won its own role, since it is now routinely an assessment tool in monitoring patients in high instable risk surgeries.

Despite the development around TEE technology, the most recent update in cardiac imaging is the intracardiac echocardiography. Its applications are still limited, but in the next future are expected to expand to support several procedures and fulfilled deficiencies of other methods. Meanwhile, iTEE is the most widely accepted tool for intraprocedural cardiac monitoring (Orban *et al.* 2013, Vitulano *et al.* 2015).

Objectives

The aim of this analysis is understand the evolution of the use of intraoperative TEE both in cardiac and noncardiac surgeries and as a secondary goal comprehend the patterns to achieve technic competency.

Material and Methods

A literature review was carried out identifying relevant clinical studies published after 2010 covering a 6-year period from 2010 to 2016. PubMed and Google scholar were the main search engines used in this study. Transesophageal echocardiography, transesophageal echocardiography in cardiac surgery and transesophageal echocardiography in noncardiac surgery were the used keywords.

Clinical relevance

TEE can provide a low risk, safe and prompt diagnostic information in intraoperative period. Its use is developing beyond the cardiac operating theater and assuming potential clinical influence; consideration should be given to utilizing this valuable imaging modality in other appropriate clinical situations.

Discussion

1. Basic ultrasound principles

Echocardiography is an imaging and diagnosis technique for cardiac structures and function, which is based on the principle of ultrasound (US) waves emission by a transducer and US reflection in contact with a reflective surface. The transmitter records the time since it was issued the pulse until the echo is received (reflected wave) and with this the distance from the source, since the speed of the wave emitted and reflected is the same. The waves received are amplified, processed and translated into image on a monitor. In turn, the strength of the echo depends on the intensity of the impulse, on the acoustic characteristics of the reflecting surface, on the angle at which the pulse reaches the reflecting surface and its dimension relative to the size of the ultrasound beam. The great reflection echo is obtained in the angle perpendicular to the surface (90°). When the difference between surface's densities is large, greater will be the strength of the reflected waves, since acoustic impedance depends on density and propagation velocity of the waves in the tissue. Other interactions occur with the emission of these waves on the body surface, such as refraction, scattering and attenuation, however they are not related to image production (Perrino and Reeves 2008, Szabo 2013).

Two-dimensional (2D) echocardiography is the main pillar of the echocardiographic examination, radiating sequentially ultrasound pulses across a cardiac sector and permitting visualize shape and lateral motion.

Several advances in ultrasound technology, such as multiplane and multifrequency probes and more recently, matrix array, digital image acquisition and processing and colour Doppler have increased the successful use of TEE in surgical practise (Vegas *et al.* 2013).

2. Transesophageal ecocardiography

Transesophageal ultrasound was first reported in 1971 to measure flow in the aortic arch. TEE uses sound waves to create high-quality moving pictures of heart and its blood vessels that involves a flexible tube or probe with a transducer at its tip, this probe is guided down throat, esophagus and stomach providing more detailed pictures of heart and great vessels, as esophagus is directly behind (Perrino and Reeves 2008).

Due to its unique properties, TEE provides higher resolution images and is less vulnerable to inter-user variability or patients factors, such obesity and ventilation, since has a retrocardiac position compared with transthoracic echocardiography (Arntfield *et al.* 2015).

The modern era of TEE permit real-time three-dimensional (RT 3D) echocardiography, in which is possible to view structures from multiples perspectives and appreciate individual patient anatomy. It is proved its accuracy and reproducibility of 3D imaging for ventricular volumes and mass, as well as valvular morphology and function. Firstly introduced in the year 2000, the sustained improvement of 3D technology has led to its widespread accessibility and its emergent utility. Matrix TEE transducer include both area and depth of the imaging plane, demanding less manipulation of the probe compared with 2D TEE examination. 3D TEE protocol habitually begins with RT imaging modes and subsequent, gated 3D data set should be obtained from midesophageal views to determine the overall function of left and right ventricles and evaluate valves structure. The advantages of RT 3D TEE are notable when compared with 2D TEE with lower interobserver variability in some parameters, better reproducibility and more accurate measures (Vegas and Meineri 2010, Lang *et al.* 2012).

To provide better images, gastric contents should be aspirated. Conscious sedation is recommended for awake patients since it is a semi-invasive procedure. The patient is typically placed in lateral decubitus position and the operator stands faced to the patient on the left-hand side of the stretcher. The insertion of the probe should be shortly after intubation and gently through posterior oropharynx, without perception of great resistance, carefully with position of transducer elements anteriorly. A lower jaw maneuver can be necessary or aid of a laryngoscope (Galhardo 2010, Hahn *et al.* 2013).

The nomenclature respected the transducer location in the digestive tract (upper esophagus, mid esophagus, transgastric, deep transgastric), description of the image plane (longitudinal and transversal axis) and the main structure evaluated (Perrino and Reeves 2008).

3. Intraoperative transesophageal echocardiography

The use of TEE in the operating room is regularly elected over transthoracic echocardiography due to its superior image quality and the ability to assess cardiovascular anatomy and function without surgical disturbance (Jerath *et al.* 2011).

Initially considered as a noninvasive tool for monitoring the left ventricle function, since then its use has expanded and now has become a standard monitoring and diagnostic tool for the management of patients undergoing cardiac and noncardiac surgery (Chilkoti *et al.* 2015). TEE changed image diagnose and monitoring in anesthesiology practice. First by identifying pathologies early in the surgery, leading to modifications in perioperative and surgical managing, secondly by giving continuously feedback to the anesthesiologist about anatomical and function transformations and allowing to anticipate when hemodynamic instability is likely to occur (Royse *et al.* 2000).

Intraoperative transesophageal echocardiography is performed on surgical patients during surgical period. Patients are typically fully anesthetized and intubated and the placement probe requires different maneuvers and precaution to prevent dislodgement of the endotracheal tube. The sequence of cuts has not been established, most operators choose begin with cuts that most likely will offer relevant information to the clinical case in question, completing the exam with the acquisition of other images. Occasionally, a complete exam is not possible due to anatomical variations or clinical conditions (Vegas and Meineri 2010, Hahn *et al*. 2013).

The basic TEE exam consensus statement suggests that focusing the basic perioperative TE examination on 11 of the most relevant views (attachment 1), instead of 28 views in a comprehensive examination (attachment 2), can provide adequate information for diagnosing certain etiologies of hemodynamic instability and general monitoring in surgical patients. If a specific diagnose is suspected, consultation with an advance echocardiographer is indicated (Reeves 2013). These 11 views should be performed for each patient. Appropriate extension to a comprehensive examination may be necessary if complex pathology is obvious and it is encouraged whenever possible. Preferably iTEE should be preceded by comprehensive preoperative TEE or TTE (Hahn *et al.* 2013, Wally and Velik-Salchner 2015).

This instrument has an increasing role in real-time monitoring of preload status of both right and left sides, systodiastolic dysfunctions, cardiac contractility through wall abnormalities, intracardiac air or thrombosis.

A new miniaturized monoplane disposable TEE probe has been recently trialed in critical care and cardiac surgery, but its potential use in noncardiac surgery for the non-expert echocardiographer is warrant investigation (Barber and Fletcher 2014).

4. Clinical indications and applications

In 2014, American Society of Echocardiography and SCA published the most recent guidelines to perform a comprehensive TEE examination; the document does not address basic perioperative TEE, which is a noncomprehensive examination for intraoperative monitoring and evaluation of hemodynamic instability. The last mentioned are especially for intraoperative imaging and do not included some views important to other applications of TEE. Other guidelines for practice developed by ASE and SCA in 2010 provide the physician support in determining the appropriate application of iTEE in order to improve the outcomes based on the strength of supporting evidence (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Hahn *et al*. 2013).

The main indications to use iTEE are recommended for cardiac and thoracic aortic surgery, catheter-based intracardiac procedures and noncardiac surgery. For adult patients without contraindications, TEE should be used in all open heart and thoracic aortic surgical procedures and should be considered as well in coronary artery bypass graft surgeries. In small children, the use should be based on case-by-case due to unique risks among this population. For patients undergoing transcatheter intracardiac procedures, TEE should be used in valve placement and repair, septal defect closure or atrial appendage obliteration, and may be used in other considered catheter procedures. For noncardiac surgery, TEE may be used when type of the elective surgery or the patient's known or suspected cardiovascular pathology might result in severe hemodynamic, pulmonary or neurologic compromise. In case of unexplained life-threatening circulatory instability perseveres despite corrective therapy, iTEE should be used as well (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010). These guidelines combined opinions from experts, ASE members and literature review; they are dated of 2010 and through this work, it is clear that literature in the past 5 years developed in a mode that iTEE is increasingly expended for several other indications with evidence-based. Thus the authors of this work suggest a new paper addressing updated practice guidelines.

Known the many uses of TEE and the potential for overuse or unnecessary use, appropriate use criteria approach is an advisable methodology when considering indications criteria. However the most recent publication for echocardiography included fifteen scenarios for TEE, it did not included intraoperative indications (American College of Cardiology Foundation Appropriate Use Criteria Task *et al*. 2011).

5. Limitations and complications

The main contraindications are related to pathologies in oropharynx, esophagus or stomach. Patients with relative contraindications should be assessed on a case-by-case basis to establish if the benefits exceed the potential risks of complication (Hilberath *et al.* 2010). For patients with structural and anatomical handicaps, a new miniaturized monoplane disposable TEE probe has been recently trialed in critical care and cardiac surgery, but its potential use in noncardiac surgery for the non-expert echocardiographer is warrant investigation (Barber and Fletcher 2014).

Appropriate qualification and continuous training are necessary in order to assure the competence of the examiner and prevent operator-related complications. Dobbs *et al.* (2014) conducted a large international web survey to better understand global practice of iTEE in adult cardiac surgery and found that the main barriers to the use of TEE were the lack of resources (equipment and personnel).

The familiarity of the complications and their risk factors can contribute to their early detection to get better prognosis. Kim *et al.* (2015) described a rare case that a patient poor cooperation and insufficient mild sedation led to a hypopharynx lesion resulting in a deep neck infection. Detection of cutaneous emphysema and pain throat complain as a TEE complication diagnoses permitted a fast intervention. The use of TEE in operating room can take more risks than in awaken patients as the example below. The TEE complications in such patients tend to be later and so an underestimation of its prevalence neglects its importance (Chilkoti *et al.* 2015). A large systematic review in esophagus perforation induced by TEE found that elderly women in the OR were the group more stricken. It was verified also that it occurred when there are no known preoperative risk factors, what suggests that screening for high risk factors don't exclude probability of perforation (Sainathan and Andaz 2013). This finding reinforces the role of the operator to detect early and smooth signs of complications during and right after the procedure, since doesn't seems feasible to eliminate completely the risk. The delay of detection of such critical complications can lead to fatal consequences.

TEE precision relies on good view acquisition. The misinterpretation of what is normal and abnormal anatomy can occur and it is decreased with a certificated operator (Wally and

Velik-Salchner 2015). TEE does not allow direct pressure measurement and the filling pressures are represented visually. It is possible to have an estimation of the size of all cardiac chambers but does not give numerical values (Feltracco *et al.* 2012).

6. Cardiac and aortic surgery

TEE not only is a clinical beneficial modality to influence anesthetic and surgical decision-making in cardiac surgery but also a cost-effective one. Canty *et al.* (2015) found that transesophageal echocardiography can predict and monitor for left ventricular distention, which is common in this surgeries.

Perhaps one of the most valuable contributors of 3D TEE in the OR is the assessment of the left ventricle (LV). The accuracy of LV volumes and function resembles cardiac magnetic resonance image (cMRI). As technology continues to grow, LV volumes and ejection fraction became easy and quick values analysed during surgery as early detection of wall motion abnormalities, helping evaluating patient cardiac function status intraoperatively (Ferreira *et al.* 2013, Reeves 2013).

Left ventricle (LV) mass is a commonly used predictor of cardiovascular disease morbidity and mortality. During cardiac surgery, LV mass can be calculated by multiplying the LV myocardium volume by its weight through iTEE, permitting diagnose LV pathology, such hypertrophic cardiomyopathy (Ferreira *et al.* 2013). This is remarkably useful in non-elective surgeries where cardiac abnormalities are found.

Even in relation to the LV, the assessment and management of left ventricular diastolic diameter and area can be used to diagnose hypovolemia and monitor fluid therapy.

Evaluation of RV function should be routinely performed since it has a very useful significance predicting morbidity and mortality in cardiac surgical patients, particularly in hypotension (Reeves 2013). While gold standards for RV function are cMRI and radionucleotide ventriculography, TEE seems to be the most feasible tool to its evaluation in the OR. 3D technology permits complete assessment of RV volumes, anatomy, geometry and ejection fraction. With this capability, it is expected that RV imaging and function become part of a comprehensive TEE examination, emphasizing the influence of this evaluation (Ferreira, Choi et al. 2013, Ramakrishna, Gutsche et al. 2016). Although, iTEE is not the gold standard for pulmonary embolism (PE), echocardiographic findings consistent with acute PE are RV dysfunction an atypical wall motion abnormalities of RV free wall (Reeves 2013).

RT 3D TEE can accurately assess location, attachment and size of intracardiac masses as atrial and ventricular septal defects, simplifying surgical planning (Hanna *et al*. 2010, Saric *et al.* 2010, Vegas and Meineri 2010). Myxomas are the most common cardiac tumors and may arise in any of the four cardiac chambers, usually in the left atrium (LA). Observing the relation between LA and mitral valve (MV) it is possible to predict certain dysfunction when tumors are large enough or their location covers MV area (Teng *et al.* 2015). Yamagushi and Koide (2015) reported a case in which a masked mitral regurgitation was only detected after tumor resection in a second iTEE, nevertheless it permitted support decision-making for appropriate MV procedure. The authors reinforced the idea that TEE should be used persistently to evaluate the possible presence of MV dysfunction before and after tumor resection. In addition, Dharmalingam and Sahajanandan (2014) demonstrated a shifting in surgical plan in a man with right atrial myxoma, highlighting the importance of TEE characterizing cardiac masses. TEE performed intraoperatively gave specific information's about the attachment and extent of the myxoma. Among valvular masses, the most known are infective endocarditis vegetation's, TEE is recommended for surgical cases, refining surgical manage (Methangkool *et al.* 2014, Yong *et al.* 2015).

6.1 Valve surgery

Valvular heart disease is an independent risk factor for perioperative mortality and morbidity. In valve surgery, TEE plays a particular role, since it allows controlling the immediate results of surgical reconstruction or replacement and provides baseline data for postoperative care (Peterson *et al*. 2003, Gouveia *et al*. 2011).

New 3D technology reduced technical and quality problems of 2D echocardiography and has resulted in widespread use in patients with valvular heart disease (Shiota 2014).

6.1.1 Mitral valve surgery

Surgical repair of the mitral valve is being progressively implemented to treat severe mitral regurgitation, it is an excellent treatment option with low-risk and is highly durable. One of the strongest indications for iTEE is evaluation MV during repair or replacement. The MV apparatus, function and the pathological segments are evaluated under general anesthesia, as well as other risk factors that can be assessed for surgical repair and correct placement of the cannulas used for CPB in minimally MV repair surgery (Ender and Sgouropoulou 2013, Sidebotham *et al.* 2014). When a non-systematic approach is used to assess mitral valve morphology, like in perioperative period, there is a good agreement between TEE and surgical findings (Peterson *et al.* 2003).

Considering postoperative evaluation of MV repair or replacement, 3D TEE has been shown to simplify visualization of the entire structure of the new artificial valve and its function.

Qualitative imaging of 3D TEE is more suitable for visualize anatomy and locating pathologies whereas quantitative analysis of 2D TEE is more accurate for measurements and quantifying severity. In addition, color Doppler 3D TEE can show the right location of paravalvular MR, helpful for transcatheter closure of leaks with immediate surgical correction. It is necessary to exclude also mitral stenosis, assess ventricular function and other vascular complications of the surgical procedure (Ender and Sgouropoulou 2013, Ferreira *et al.* 2013, Hien *et al.* 2014, Maslow *et al.* 2014, Shiota 2014, Sidebotham *et al.* 2014, Maslow 2015, Maslow 2015, Ramakrishna *et al.* 2016). Even some echocardiographic variables are recently identified as independent risk predictors of procedural failure (Lubos *et al*. 2014).

As new minimally invasive and even off-pump techniques for MV repair/replacement become well known, the role of TEE turns out to be essential for monitoring this less invasive approaches since simplifies the surgery, improves outcomes and is highly rewarding (Ender and Sgouropoulou 2013).

6.1.2 Aortic valve surgery

For several years, TEE is used to see immediate results and, if necessary, for reintervention to improve the adequacy of prosthetic valve in percutaneous valve implantation (Grando *et al.* 2013). Besides that, iTEE is routinely performed after cardiopulmonary bypass (CPB) to evaluate the adequacy of aortic valve (AoV) repair in adult population. AoV repair is an alternative approach to valve replacement with the advantages of eliminating the need of long-term anticoagulation and prosthetic-related complications such thromboembolic events and endocarditis. However, during aortic valve replacement, TEE allows sizing the annulus and confirming satisfactory function after implantation.

A pre-repair TEE usually focuses on anatomy and function of the AoV, planning the viability of the AoV procedure. An immediate post-repair evaluation provides important information about the quality of the surgical repair (coaptation's level relative to the annulus and length of cusp coaptation) and mechanisms of any residual aortic insufficiency (AI). In some cases, the amendment of contributing lesions should be done concurrently to guarantee a suitable result. If the repair is considered inadequate, an echographic image of the valve is absolutely critical and will guide the surgeon in an effort to correct the causes of residual AI during re-evaluation, or if the repair is no longer reasonable, the decision to replace the valve may be made (Van Dyck *et al*. 2010, Hall *et al.* 2014, Stern *et al.* 2015).

6.2 Coronary surgery

The utility of TEE in revascularization surgery should be considered to refine preoperative diagnosis, detect new unsuspected pathology, manage both anesthetic and surgical plans appropriately and evaluate surgical results (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010). Evidences show that it's the most sensitive method in the diagnosis of myocardial ischemia, detecting segmental wall abnormalities less than a minute after inadequate myocardial perfusion, preventing an unsuccessful revascularization. In addition, it can also detect incidental cardiac conditions that may require surgical intervention. The detection of these alterations modifies the therapeutic conduct (Carlos Galhardo Júnior 2011, Maldonado *et al.* 2015).

In patients undergoing coronary artery bypass grafting, atherosclerotic disease can lead to perioperative complications. Several studies showed that the severity of the atheroma found in iTEE is strong related to stroke and other negative outcomes after coronary artery surgery (Denny *et al*. 2015). Nowadays, literature is more oriented in preoperative evaluation of patients, so their risk factors can be promptly added to surgical and anesthetic planning. Preoperative CT angiography shows to be superior to TEE in identifying aortic atheroma (Park *et al*. 2010, Chatzikonstantinou *et al*. 2012).

Even in something as rare as coronary aneurisms, TEE could detect intraoperatively dilations of these vessels and equally helped to approach complications during these techniques (Swaminathan *et al*. 2003, Sawai *et al*. 2015).

6.3 Aortic surgery

iTEE should be used routinely in thoracic aortic surgery (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010). Currently, TEE is considered the first-line exam in the diagnosis of thoracic aortic dissection (AD) in hemodynamic instable patients; true and false lumens can be difficult to distinguish and so the presence of blood flow in true lumen and slow or absence of flow in false lumen can be perceived through TEE colour Doppler. It has proven specifically valuable for choosing the landing site for the proximal stent by clarifying areas of atheroma and calcification that would otherwise not be perceived by angiography and could interfere with stent adhesion. iTEE is highly useful during endovascular treatment in complicated descending AD. It allows identify true and false lumens by guide wiring entrance, false lumen thrombosis and anterograde and retrograde flows, evaluate correct stent-graft positioning, possible leaks and small re-entry tears, all critical evidence with prognostic implications (American Society of and Society of

Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Galhardo 2010, Barber and Fletcher 2014, Hall *et al*. 2014, Tan and Fraser 2014). Orihashi *et al.* (2014) in a recent case report showed that TEE besides being useful in stent guidance during open stent graft procedure that also it was a valuable tool by diagnosing a stent migration occurred intraoperatively. It looks intuitive to think of TEE as an accurate check-up tool in operative period.

Although, recent guidelines recommend its use, TEE has not been used universally. Little is know about the impact of TEE in the management of AD. In literature, some studies have been performed that corroborate its role as suggested in recent guidelines. In abdominal aneurysm surgery, acute AD is an atypical and fatal complication that can develop during open repair of an abdominal aortic aneurysm. Kainuma *et al.* (2015) reported a case describing the usefulness of TEE for the diagnosis and operative decision-making during the management of an acute AD. TEE revealed the existence and extension of the dissection, presence of AR and absence of myocardium and coronary involvement as well as pericardial effusion. Thorsgard *et al.* (2014) in a retrospective study showed that TEE data led to a change in planned surgery in 39% of the patients in acute type-A AD. According to the previous literature, this number is a little higher (6-30%) but its specific for this surgery and it can be as high as in other emergent surgery procedures, entirely distinctive of the complete data that is required in an elective surgery patient.

6.4 Pediatric and congenital heart disease surgery

As in adult population, iTEE in infants who undergo cardiac surgery is a valuable tool that confirms diagnosis by other imaging devices and can identifies additional pathological disorders. Before surgical correction, TEE confirms diagnosis and after surgical repair assesses correct fix and detects remaining lesions. Recent study showed that in almost 6,5% of the patients undergoing surgery for congenital heart disease (CHD), iTEE changed surgical plan and allowed immediately repair of surgical abnormalities (Garg *et al*. 2009, Guzeltas *et al*. 2014).

TEE is used in several different surgical procedures in CHD such atrial septal defect (ASD), ventricular septal defect (VSD), valve replacement, atrioventricular canal, combined ASD and VSD or combined VSD and pulmonary stenosis, valve reconstruction, subaortic stenosis resection, reoperation and neo-natal surgery, Fontan procedure, Tetralogy of Fallot (TF), Ebstein anomaly and even in extracardiac procedures (Garg *et al*. 2009).

In pediatric population, TEE has adverse effects too. Compression of the airway leading to desaturation and hemodynamic instability are the most common side effects in younger patients and trauma during insertion and extubation, especially in neonates. Technological advances permitted the accessibility of pediatric probes in surgeries for CHD in children. The use of these probes is limited in small infants weighing less than 5 kg, but a weight-based algorithm can help determine neonates at risk for iTEE probe insertion failure. It was suggest that smaller TEE probes might benefit this patient population, once some heart diseases need intervention right after birth. Small probes with 5mm could be used in neonates with less than 2,5kg (Garg *et al.* 2009, Wellen *et al*. 2013). Zyblewski *et al.* (2010) established that the use of new multiplane micro-TEE provided high quality, useful diagnostic images without hemodynamic or ventilation compromise in small infants undergoing cardiac operations. The innovation is especially important with the growing trend towards complete repair of complex structural heart disease in toddlers (Wellen *et al*. 2013).

In a high-risk surgery as TF, iTEE revolutionized cardiac evaluation during the procedure, assessing primary anomalies, immediate surgical revision, residual defects and hemodynamic monitoring. TEE improved clinical outcomes in these patients (Motta and Miller-Hance 2012).

Although well described in adult population, TEE predictors' of aortic regurgitation (AR) after AoV surgery may not be appropriate in pediatric population, given the disparities in underlying diseases. So Stern *et al.* (2015) studied which intraoperative post-CPB TEE variables could predict higher risk of early reoperation for recurrent AR in children with congenital aortic valve disease. They found that higher risk was present with coaptation asymmetry, measured through the difference in percentage between short-axis coaptation lengths. This parameter is a simple calculation in standard TEE view, strengthening the value of TEE in decision-making process. The information could lead to a return to bypass to improve coaptation symmetry and so preventing reintervention in these children. Still, since this was a small group study, a larger sample size studies could corroborate these finds.

In congenital mitral valve disease, *Song et al.* demonstrated the utility of iTEE in mitral valve replacement, which diagnosed an incorrectly placed prosthetic valve permitting proper implantation after reinitiating CPB (Song *et al.* 2015).

Transesophageal echocardiography plays also a crucial role in performing minimally invasive surgical closure of cardiac defects, showing more accuracy about real dimension of the defect than transthoracic echocardiography (Bai *et al.* 2012).

7. Noncardiac surgery

The questions faced in the OR during a noncardiac surgery are rather distinctive. TEE can be an important tool for patients with significant comorbidities or if hemodynamic instability is anticipated or occurs intraoperatively (Rebel *et al*. 2012).

Hemodynamic instability and quick changes in volume are serious complications, the rapid recognition and identification of these situations and their causes are the basis for the treatment. The impact of direct visualization of cardiac structures has the potential to provide important information on cardiovascular function relevant to hemodynamic management. In complex noncardiac procedures such has liver transplantation, due to surgical manipulation or blood loss, the probability of hemodynamic instability is high and so iTEE can add important information to patients managing.

Moreover, hypotension and arrhythmias are frequently associated with hemodynamic instability. The first one can be due to cardiac failure, hypovolemia or reduced peripheral resistance (RPR). Even in acute blood loss, RPR can be existent along with signs of hypovolemia. Consequently, evaluations of cardiac output and cardiac preload are important factors in intraoperative examining. Many of these variables demonstrate good correlation when compared with more invasive techniques, even in the case of detecting acute hemodynamic changes, TEE is superior to pulmonary artery catheter (Galhardo 2010).

To show an original and astute use of this device in noncardiac surgery, in 2014 it was described a rare case report of which an external masse (transplanted liver) caused a cardiac compression resulting in several episodes of supraventricular tachycardia right after the transplant. This symptomatic myocardial compression by the liver was guided and confirmed via RT-TEE imaging with a successful resolution (Stoll *et al.* 2015). Even in obstetric surgery, Cho *et al.* (2012) reported a rare case of abrupt hemodynamic instability in a woman during a vaginal hysterectomy, iTEE was performed and a right atrium thrombus was identified.

Different small case reports in literature are showing several uses of TEE in noncardiac surgery, so it is now advisable to have systematic large studies sets supporting its powerful value.

7.1 Liver transplantation

Patients undergoing orthotopic liver transplantation (LT) may present cardiac dysfunction from cirrhotic cardiomyopathy or pre-existing coronary artery disease. In addiction, patients are at risk of hemodynamic instability due to several causes, blood loss, obstructed inferior vena cava flow, increased workload, embolization, and reduced systemic vascular resistance. These circumstances can be assessed by TEE and make a difference in patient's outcome, creating an opportunity to identify early and prevent future complications (Rebel *et al.* 2012). Concerns about these conditions may deter anesthesiologists from practice intraoperative TEE. Particularly in patients with pulmonary hypertension, RV dysfunction can be a complication during surgery and it is recommended performed a basic iTEE, allowing quick determination of cardiac status and therapeutic attitudes (Reeves 2013). Recent guidelines listed esophageal varices, coagulopathy, thrombocytopenia and recent upper gastrointestinal bleeding as contraindications to use TEE, however literature considered that it is relatively safe despite the risk of variceal hemorrage (Markin *et al*. 2015). A recent retrospective study about iTEE in orthotopic LT showed that it was relatively safe procedure in patients with documented esophagogastric varices and coagulopathy, with a low incidence of major hemorrhagic complications (0,43%) (Pai *et al*. 2015). The grade of the varices looks to be related with the probability of bleeding, although grade IV varices is an absolute contraindication, in grades I and II, TEE has been performed safely (Burger-Klepp *et al.* 2012, Pantham *et al*. 2013). In addiction, a contemporary retrospective study in University of California, population of 433 patients with model for end-stage liver disease (MELD) score 25 or higher demonstrated that iTEE was not associated with major gastroesophageal and hemorrhagic complications during LT (Myo Bui *et al*. 2015).

Nevertheless, there are some methods that decrease the risk of variceal rupture during iTEE in liver transplantation, such as experienced operators with strict vigilance, gastroenterology consultant and correction of coagulopathy before the TEE procedure (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Hilberath *et al.* 2010, Hahn *et al*. 2013).

Considering the great dimension of this surgery, hemodynamic patterns are very important to monitor, and TEE has shown accuracy to determine essential changes, such stroke and end diastolic volumes, wall abnormalities, air embolism, shunts, effusions and valvular pathologies. Influence of TEE on fluid therapy during liver transplantation is also well documented in literature, up to 50% in some series (Hofer *et al*. 2004).

Although transgastric views are limited, the short axis view gives a better assess to the circumference of the left ventricle by overpassing posterior retraction of the stomach (Feltracco *et al.* 2012).

The less invasive option to monitor cardiac output is arterial pulse waves analysis but this measurement cannot be reliable during liver transplantation. With the currently technology available, TEE has been the most direct measurement of cardiac filling, offering the benefit of identifying also a variety of other diagnosis that can alter surgical procedure and change the patient's outcome (Rudnick *et al.* 2015).

7.2 Neurosurgery

During medical history, the sitting position in neurosurgery has been an important approach to improve surgical field. The passive drainage of the spinal fluid and blood, as well the access to deep structures without excessive cerebellar retraction are conditions that empower this method. However, the risk of air venous embolism is a serious complication of this method and some authors even contraindicate this methodology when the patient has a patent foramen ovale (Barber and Fletcher 2014). The diagnostic of a right-to-left shunt also changes the surgical approach, since these patients are vulnerable to embolism in the sitting position. Still, recently it was demonstrated that TEE has an excellent sensitivity to intraoperative detect air in the right atrium with real-time data and a visual quantification, and so it's possible to say that the sitting position can be relatively safe when TEE monitoring is used (Ganslandt *et al.* 2013, Reeves 2013).

7.3 Orthopedic surgery

There is a whole spectre of cardiac abnormalities contributing to morbidity and mortality in orthopedic surgery. It is known that TEE has utility in managing patients with acute hemodynamic instability in noncardiac surgery. These complications can be caused by several cardiovascular risk factors and events. As the population remains to age, comorbidities especially cardiovascular disease are more common to deal in the OR. In arthroplasty procedures, pulmonary embolism is the most important complication associated with cardiopulmonary arrest. Several cases are demonstrating the use of TEE on clinical decision-making to acute resuscitation of these patients (Memtsoudis *et al.* 2006, Rebel *et al.* 2012, Garvin *et al.* 2013). Although in practice guidelines the use of TEE is not recommended, patient's cardiovascular status should be evaluated always if some cardiovascular pathology known or suspected can result in hemodynamic, pulmonary or neurologic compromise (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010).

8. Training and competencies

Echocardiography is a multifaceted technical expertise and the restrictive factor is the availability of trained operators and equipment. *Dobbs et al.* conducted a large international web survey to better understand global practice of iTEE in adult cardiac surgery, the results corroborate that the main barriers to the use of iTEE in 27 countries were the lack of resources (equipment and personnel) (Dobbs *et al*. 2014). However, TEE is being used more often and by more qualified personnel than in previous studies. These results are a call to order to establish basic TEE training programs among novices anesthesiologists as well as among non-skilled seniors, permitting a new generation of physicians who dominate this technique and know how to take advantage in clinical practice of its potential.

Demonstration of competence in iTEE is usually accomplished by successful conclusion of a training program and passing an examination (Barber and Fletcher 2014).

It is recommended to follow current existing accreditation pathway if one requests to acquire TEE competence. In cardiac surgery, advanced level of echocardiography is required, full diagnostic skills with Doppler modes domain and 3D imaging. Yet, it is possible to a trainee who spends a year in cardiac anesthesia training programme develop required skills to perform a full TEE examination if the equipment can be made accessible. The updated guidelines defined the training process, prerequisite echocardiographic knowledge, a training components and duration, appropriated environment and supervision. Basic perioperative TE training is mostly dedicated on to intraoperative monitoring, whereas advanced training aims on specific diagnoses (Sharma and Fletcher 2014, Peng *et al*. 2015).

The European Society of Echocardiography together with the European Association of Cardiac Anaesthesiologists offers a certification in TEE through a two component evaluation, a multiple-choice examination and the submission of a log book of 125 PTE exams performed personally in 1-year period; from these studies, 15 cases are selected randomly and posterior graded by external examiners. The maintenance of certification requires at least 50 TEEs per year (25 to maintain a basic certification) and continuing medical education with a physician at the advance or director level of 30 hours in 5 years. The demands for advanced or director level are not specified in these consensus but in the ASE and SCA guidelines for training in perioperative echocardiography is required 150 and 300 performed TEEs, in advance and director levels, respectively (American Society of and Society of Cardiovascular Anesthesiologists Task Force on Transesophageal 2010, Hahn *et al*. 2013, Reeves 2013, Peng *et al.* 2015).

New technology allowed the conception of echocardiographic simulators; several studies have been shown an important role in future training of echocardiography skills without routine access to patient environment, demonstrating superior learner outcomes. Online simulators may be promising too with basic TEE training programs, as apprentices could practice in every time and place. These platforms are especially important to TEE-naïve since improves expertise, speed learning and comfort with TEE (Jerath *et al.* 2011, Damp *et al*. 2013, Vegas *et al.* 2013, Mitchell *et al.* 2014, Arntfield *et al.* 2015).

Even short workshops among those who have already basic transesophageal echocardiographic skills could contribute to improve their abilities and so minimize operator related complications during procedures.

Conclusions

Transesophageal echocardiography information can be very valuable in intraoperative period providing or restoring hemodynamic stability. It should be used as an auxiliary tool to have more comprehensive understanding of the patient's cardiovascular physiology and manage a most adequate surgical intervention. It provides real time images of both heart and great vessels anatomy and can also evaluate their function. With low risk depending together of experienced skilled operator and patient's anatomy and comorbidities, it is an important perioperative tool that can changes patient's outcome.

Systematic large sets studies are recommendable for access its role in noncardiac surgery, especially since it has been a promising in monitoring patients in liver transplantation. Accordingly, it is desirable the adoption of transesophageal echocardiography basic skills within anesthesia practice worldwide. Education is the most influential instrument to contribute in shifting the anesthesiology community's standpoint of TEE use in daily clinical practice.

The crucial worth of the monitor is how the information obtained is interpreted and used to alter the patient management. The risks and benefits should always be considered, anesthesia and surgical teams should operate together in order to promptly analyze the evidence and act in accordance with the best interest of the patient. Once expert and skilled, the anesthesiologist increases his position in perioperative medicine, contributing with vital clinical evidence for anesthetic-surgical procedure.

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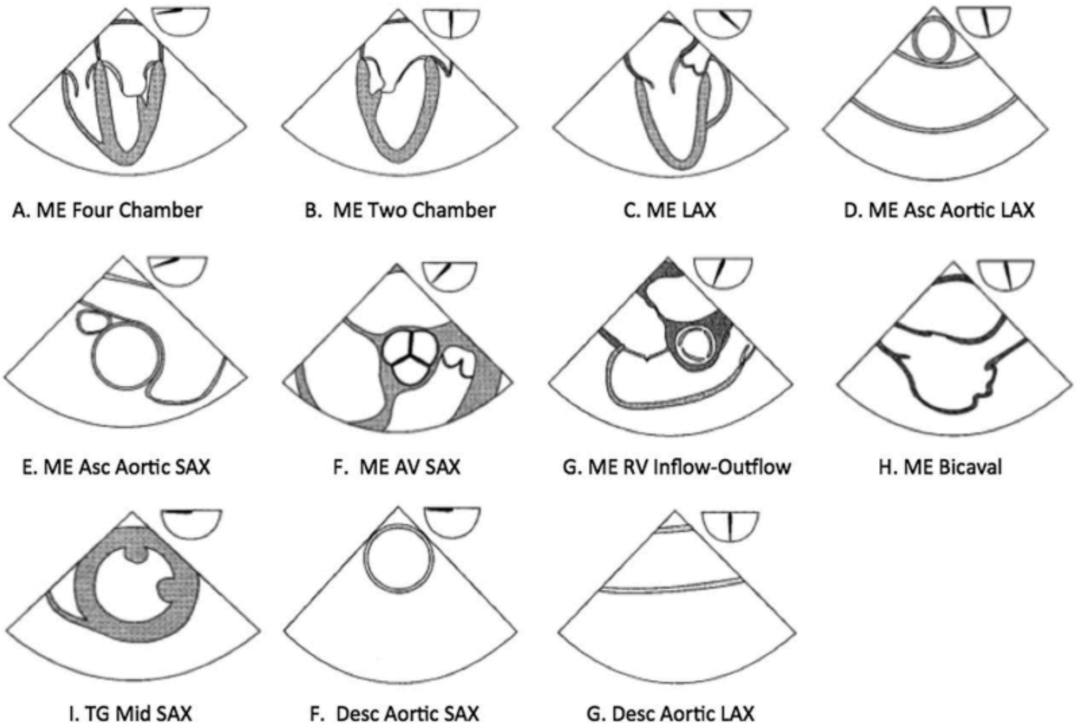
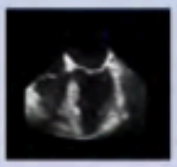
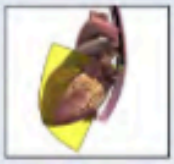
Attachments

1. Cross-sectional views of the 11 views of the ASE and SCA basic perioperative transesophageal echocardiography examination.

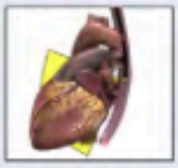
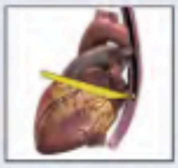


Fount: Reeves et al, *Basic Perioperative Trasesophageal Echocardiography Examination: A Consensus Statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists*, J Am Soc of Echocardiogr, 2013 (page 448); 26:443-56.

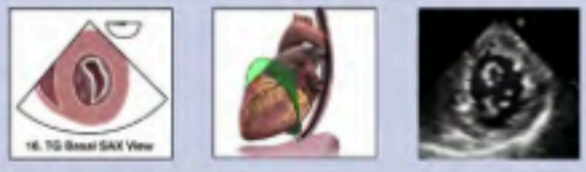
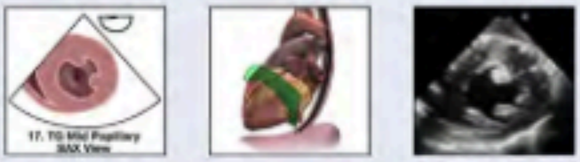
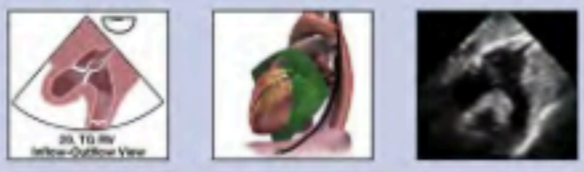
2. Comprehensive transesophageal echocardiography examination. 28 views, 3D image, the corresponding imaging plane and a 2D image.

Imaging Plane	3D Model	2D TEE Image	Acquisition Protocol	Structures Imaged
Midesophageal Views				
			**Transducer Angle:** ~ 0 - 10° **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Aortic valve LVOT Left atrium/Right atrium Left ventricle/Right ventricle/IVS Mitral valve (A_2A_1-P_1) Tricuspid valve
			**Transducer Angle:** ~ 0 - 10° **Level:** Mid-esophageal **Maneuver** (from prior image): Advance ± Retroflex	Left atrium/Right atrium IAS Left ventricle/Right ventricle/IVS Mitral valve (A_3A_2-P_2P_1) Tricuspid valve
			**Transducer Angle:** ~ 50 - 70° **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Left atrium Coronary Sinus Left ventricle Mitral Valve (P_3- $A_3A_2A_1$ - P_1) Papillary muscles Chordae tendinae
			**Transducer Angle:** ~ 80 - 100° **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Left atrium Coronary sinus Left atrial appendage Left ventricle Mitral valve (P_3-$A_3A_2A_1$)
			**Transducer Angle:** ~ 120 - 140° **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Left atrium Left ventricle LVOT RVOT Mitral valve (P_2- A_2) Aortic valve Proximal ascending aorta
			**Transducer Angle:** ~ 120 - 140° **Level:** Mid-esophageal **Maneuver** (from prior image): Withdrawl ± anteflex	Left atrium LVOT RVOT Mitral valve (A_2- P_2) Aortic valve Proximal ascending aorta
			**Transducer Angle:** ~ 90 - 110° **Level:** Upper-Esophageal **Maneuver** (from prior image): Withdrawl	Mid-ascending aorta Right pulmonary artery
			**Transducer Angle:** ~ 0 - 30° **Level:** Upper-Esophageal **Maneuver** (from prior image): CW	Mid-ascending aorta (SAX) Main/bifurcation pulmonary artery Superior vena cava

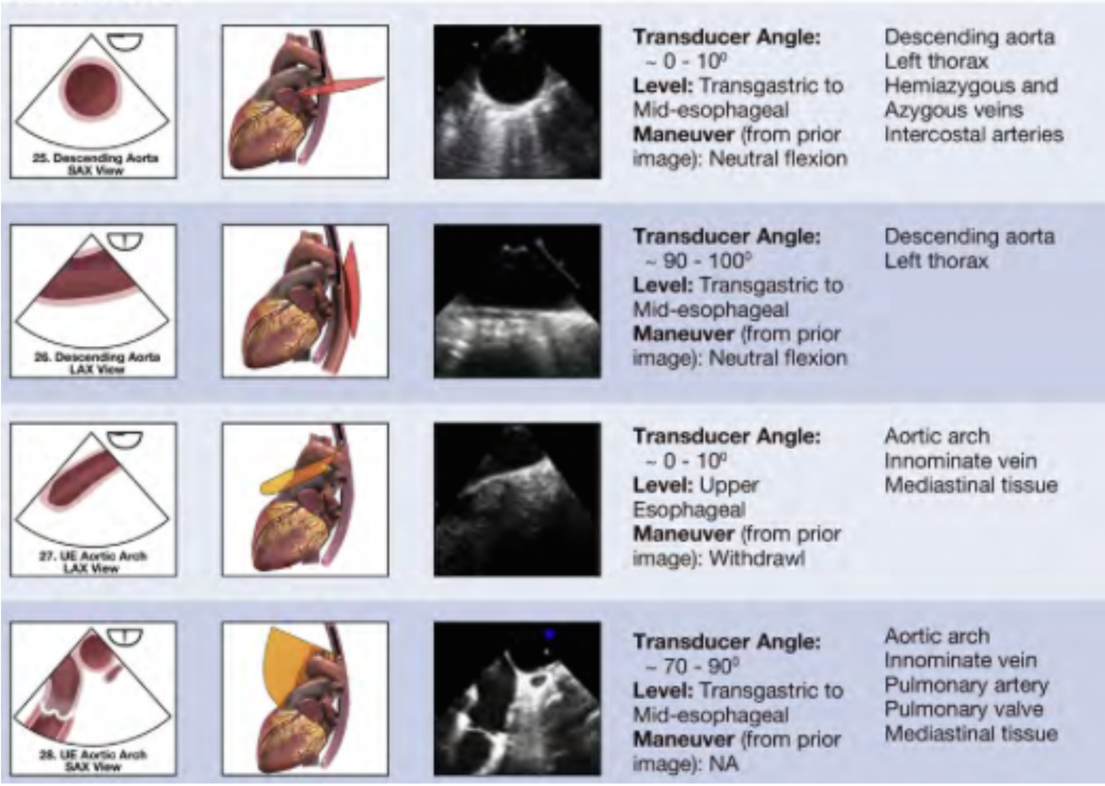
Continued Midesophageal Views

			**Transducer Angle:** ~ 0 - 30º **Level:** Upper-esophageal **Maneuver** (from prior image): CW, Advance	Mid-ascending aorta Superior vena cava Right pulmonary veins
			**Transducer Angle:** ~ 25 - 45º **Level:** Mid-esophageal **Maneuver** (from prior image): CCW, Advance, Anteflex	Aortic valve Right atrium Left atrium Superior IAS RVOT Pulmonary Valve
			**Transducer Angle:** ~ 50 - 70º **Level:** Mid-esophageal **Maneuver** (from prior image): CW, Advance	Aortic valve Right atrium Left atrium Superior IAS Tricuspid Valve RVOT Pulmonary Valve
			**Transducer Angle:** ~ 50 - 70º **Level:** Mid-esophageal **Maneuver** (from prior image): CW	Right atrium Left atrium Mid-IAS Tricuspid Valve Superior vena cava Inferior vena cava/coronary sinus
			**Transducer Angle:** ~90 - 110º Level: Mid-esophageal **Maneuver** (from prior image): CW	Left atrium Right atrium/appendage IAS Superior vena cava Inferior vena cava
			**Transducer Angle:** ~ 90 - 110º **Level:** Upper-esophageal **Maneuver** (from prior image): Withdraw, CW for the right veins, CCW for the left veins	Pulmonary vein (upper and lower) Pulmonary artery
			**Transducer Angle:** ~90 - 110˚ **Level:** Mid-esophageal **Maneuver** (from prior image): Advance	Left atrial appendage Left upper pulmonary vein

Transgastric Views

	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex	Left ventricle (base) Right ventricle (base) Mitral valve (SAX) Tricuspid valve (short-axis)
	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex	Left ventricle (mid) Papillary muscles Right ventricle (mid)
	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex	Left ventricle (apex) Right ventricle (apex)
	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Anteflex	Left ventricle (mid) Right ventricle (mid) Right ventricular outflow tract Tricuspid Valve (SAX) Pulmonary Valve
	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Right-flex	Right atrium Right ventricle Right ventricular outflow tract Pulmonary valve Tricuspid Valve
	**Transducer Angle:** ~ 0 - 20° **Level:** Transgastric **Maneuver** (from prior image): Left-flex, Advance, Anteflex	Left ventricle Left ventricular outflow tract Right ventricle Aortic valve Aortic root Mitral Valve
	**Transducer Angle:** ~ 90 - 110° **Level:** Transgastric **Maneuver** (from prior image): Neutral flexion, Withdraw	Left ventricle Left atrium/appendage Mitral valve
	**Transducer Angle:** ~ 90 - 110° **Level:** Transgastric **Maneuver** (from prior image): CW	Right ventricle Right atrium Tricuspid valve
	**Transducer Angle:** ~ 120 - 140° **Level:** Transgastric **Maneuver** (from prior image): CCW	Left ventricle Left ventricular outflow tract Right ventricle Aortic valve Aortic root Mitral valve

Aortic Views



Fount: Hahn et al, *Guidelines for Performing a Comprehensive Transesophageal Echocardiographic Examination: Recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists*, J Am Soc of Echocardiogr, 2013 (pages 934, 935, 936, 937); 26:921-64.