实时三维经食管超声心动图对心脏瓣膜病的量化评估进展

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【摘要】三维超声心动图被认为是量化评估心脏瓣膜病最有潜力的技术,而实时三维经食管超声心动图(RT 3D-TEE)的高质量图像使其更广泛地应用于诊断心脏瓣膜病。对于二尖瓣疾病,RT 3D-TEE 被认为是最独特、有效、可信的用于理解二尖瓣复杂的解剖结构和动力学特征的工具。虽然 RT 3D-TEE 应用于主动脉瓣、三尖瓣和肺动脉瓣疾病还处于早期及持续发展的阶段,但对于术前评估经导管主动脉瓣置换术患者的主动脉瓣环径有参考价值。现就 RT 3D-TEE 在心脏瓣膜病中的应用进展进行综述,包括二尖瓣、主动脉瓣、三尖瓣及肺动脉瓣疾病。

【关键词】心脏瓣膜病;实时三维经食管超声心动图;经导管主动脉瓣置换
【DOI】10. 16806/j. cnki. issn. 1004-3934. 2020. 10. 013

Real-time Three-dimensional Transesophageal Echocardiography for Quantification of Valvular Heart Disease

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【**Abstract**】Three-dimensional echocardiography has been considered the most potential technique for quantification of valvular heart disease, while the high-quality images of real-time three-dimensional transesophageal echocardiography (RT 3D-TEE) make it more widely used in the diagnosis of valvular heart disease. Especially for mitral valve disease, RT 3D-TEE is regarded as the most unique, effective and credible tool to understand the complex anatomical structure and dynamic characteristics of mitral valve. Although the application of RT 3D-TEE in aortic valve, tricuspid valve and pulmonary valve disease is still in an early and continuous development stage, it has a reference value for preoperative assessment of aortic annular size in patients undergoing transcatheter aortic valve replacement. This article reviews the progress of RT 3D-TEE in valvular heart disease, including mitral valve, aortic valve, tricuspid valve and pulmonary valve disease.

【**Key words**】Valvular heart disease; Real-time three-dimensional transesophageal echocardiograph; Transcatheter aortic valve replacement

心脏瓣膜病发病率高,常需手术干预治疗。实时三维经食管超声心动图(real-time three-dimensional transesophageal echocardiography, RT 3D-TEE)由于不受声窗影响,以及高质量、高帧频率全心动周期成像的特点,被认为是术前量化评估瓣膜病,术中最小化手术侵入性最有潜力的工具[1]。以下将分别讨论 RT 3D-TEE 对心脏瓣膜病的量化评估进展。

1 二尖瓣病变

1.1 二尖瓣狭窄

风湿性二尖瓣狭窄(mitral stenosis, MS)是最常见的心脏瓣膜病,主要表现为瓣叶连合部的粘连、融合。对于风湿性 MS 二尖瓣口面积(mitral valve area, MVA)的评估,Karamnov 等[2]发现 RT 3D-TEE 测值较经胸超声心动图(transthoracic echocardiography, TTE)更低,提示 TTE 可能高估 MVA,其高估程度为 0. 35 cm^2;并且 Uygur 等[3]发现 RT 3D-TEE 对于 MVA 的评估具有良好的可重复性。对于风湿性 MS 的治疗,二尖瓣成形术应用虽然相对较少,但术后即刻评估是否有残余狭窄依然非常必要,此时由于压力减半时间测量的不准确性及术后即刻二尖瓣形态的改变,二维超声已无法准确测量 MVA,由于压力减半时间法对于术后即刻 MVA 的低估,RT 3D-TEE 能更准确地评

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估 MVA[4]。因此,不论是术前还是术后,RT 3D-TEE 对于 MS 的评估都是最佳选择。

1.2 二尖瓣反流

二尖瓣的内在损害,包括弹性纤维缺乏和 Barlow 病导致的退行性二尖瓣反流(degenerative mitral regurgitation, DMR),是原发性二尖瓣反流(mitral regurgitation, MR)的常见原因,而功能性二尖瓣反流(functional mitral regurgitation, FMR)通常是由于缺血性、非缺血性心肌病相关的左室功能不全[5],或持续性心房颤动(atrial fibrillation, Af)导致的左房增大所致。研究表明,RT 3D-TEE 有助于鉴别 MR 的病因[6]。

正常二尖瓣环并非位于同一个平面上,而是呈“马鞍形”,且随着心动周期其大小和形态规律改变[7]。研究表明,MR 患者二尖瓣环明显增大,其中 Barlow 病患者的瓣环扩张最为显著;通过瓣环高度和瓣叶连合间直径的比值来评估瓣环收缩期形态,发现 DMR 的瓣环马鞍形于收缩期尚存,而 FMR 的瓣环更扁平,即 DMR 的瓣环相对于 FMR 更有延展性,其瓣环动力学增强,而 FMR 的瓣环动力学减弱,这些改变将显著影响 MR 程度的评估[8],而且理解 MR 的瓣环特征也有助于成形环的选择[9]。Mahmood 等[10]利用 RT 3D-TEE 对 66 例缺血性 MR 患者的研究发现,相对于正常对照组,MR 患者前瓣环 A2 区周长、瓣环非平面角度和 P3 区穹窿角度均增大。通常认为 A2 区是纤维、刚性的区域,A2 区周长的增大说明瓣环受到牵拉进而扭曲变形,而瓣环非平面角度的增大说明瓣环变得扁平,这些特定的三维结构改变反映了二尖瓣环的重塑,而以上 3 个测值对于鉴别缺血性 MR 和其他类型的 MR 具有一定的价值,并为患者选择最佳手术干预方式和时间提供参考。

用 RT 3D-TEE 对 Af 患者的二尖瓣叶重塑和 MR 程度的研究发现,Af 伴中-重度 FMR 的患者,瓣叶总面积和瓣环面积的比值明显减小,线性回归分析发现该比值和有效反流口面积呈负相关,较小的比值提示 FMR 越明显,而预测 Af 患者是否出现 FMR 的临界比值是 1.38,瓣叶重塑可能是瓣环扩张的代偿机制,因此不充足的瓣叶重塑和重度 FMR 具有相关性[11]。另一项 RT 3D-TEE 对 Af 患者 FMR 的机制研究发现,伴随 FMR 的 Af 患者瓣环平面和 A2 区瓣连合线之间的角度更小,瓣环平面和 P2 区瓣尖线之间的角度更大,说明前瓣叶朝向瓣环方向变得扁平,而后瓣叶朝向左室腔内弯曲,这是由于左房扩张、左室形变,从而使后瓣叶受到牵拉,瓣叶连合减小而加重 MR[12]。Cobey 等[13]利用 RT 3D-TEE 观察二尖瓣反流束,发现通常呈多束并且是偏心的反流,二维近端等速表面积法假设有效反流口呈圆形,然而 RT 3D-TEE 却发现真正呈圆形的仅占 2%[14],这使二维近端等速表面积法测量有效反流口面积的有效性及精确性降低。分别对偏心 DMR 和 FMR 的 RT 3D-TEE 量化研究发现,二维近端等速表面积法明显低估有效反流口面积,低估程度分别为 8.2% 和 29.1%,造成这种差异的原因是 FMR 的反流口更细长、弯曲[15]。

使用 MitraClip 系统进行经导管二尖瓣钳夹已成为 MR 患者可选择的治疗方式[16]。RT 3D-TEE 不仅可实时引导 MitraClip 的进行,而且还可评估术后即刻瓣环重塑的逆转,这种逆转主要表现为二尖瓣环周长和前后径的减小[17]。RT 3D-TEE 对于术后成形环的形态和动力学评价也有重要价值。Ryomoto 等[18]通过研究三种不同成形环对于二尖瓣环结构和动力学的维持发现,半刚性环和刚性环能重建三维马鞍形态,从而减低瓣叶应力以增加瓣叶的持久性;而半延展性环能较好地维持瓣环动力学。因此,无论术前还是术后,利用 RT 3D-TEE 评估二尖瓣环形态和动力学都有重要的意义。

2 主动脉瓣疾病

2.1 主动脉瓣狭窄

Machida 等[19]应用 RT 3D-TEE 将三叶式和二叶式主动脉瓣进行对比研究发现,三叶式主动脉瓣是扁平的,而二叶式主动脉瓣呈穹窿形,这种特定的形状会产生测量错误。因此,针对二叶式主动脉瓣狭窄(aortic stenosis, AS)的评估,RT 3D-TEE 是更理想的工具。利用 RT 3D-TEE 直接面积测量和连续方程法评估 AS 程度发现,2D-TEE 连续方程法计算左室流出道面积会产生低估,因为其假设左室流出道呈圆形,但 RT 3D-TEE 发现其真实形状呈椭圆形,由于左室流出道面积的低估造成 AS 程度的高估,这对于中-重度 AS 的患者将显著影响其手术决策[20]。

经导管主动脉瓣置换(transcatheter aortic valve implantation, TAVI)对于高风险、严重且有症状的 AS 患者是一种可供选择的新型手术方式,RT 3D-TEE 能精确地测量 TAVI 所需主动脉根部参数,包括主动脉瓣环径、周长和面积等[21],该技术克服了 2D-TEE 只能进行矢状位测量,从而低估主动脉瓣环径的不足,并且组间和组内均有良好的测量重复性[22]。利用 RT 3D-TEE 术前评估左冠状动脉到主动脉瓣环的距离和左主干的长度,术后即刻评估人工主动脉瓣和左冠状动脉开口的距离实现了更安全、有效的 TAVI 手术的实施[23]。对于 TAVI 术后瓣周漏的发生,运用 RT 3D-TEE 测量面积覆盖指数,即直接测得的主动脉瓣环面积和人工瓣膜面积的百分比差异(1-瓣环面积/人工

瓣膜面积),有助于术前预测术后是否出现明显瓣周漏[24]。对于 TAVI 术后人工瓣膜不匹配的评估,RT 3D-TEE 由于对人工瓣叶的形态和活动性具有独特的视角,使其成为更好的评估工具[25]。

2.2 主动脉瓣反流

Sohmer 等[26]应用 RT 3D-TEE 计算主动脉瓣接合部表面积发现,主动脉瓣中-重度反流的患者比正常对照组瓣接合部表面积明显减小,这对于主动脉瓣成形术前评估是否能重建适当的瓣接合部,术后即刻评估成形术效果有重要的意义。

3 三尖瓣病变

三尖瓣是最大并且是最靠近心尖的一组瓣膜,包括纤维瓣环、三个瓣叶、乳头肌和腱索,正常的三尖瓣环呈椭圆的马鞍形[27]。Owais 等[28]通过 RT 3D-TEE 研究正常三尖瓣环发现,三尖瓣环是一个具有动力学的非平面结构,其面积和周长随心动周期改变,最大值出现于舒张末期,分别为(12.5±3.1) cm^2 和(12.8±1.4) cm,前、后瓣区域间的瓣环动力学最大,而前、隔瓣区域间的瓣环动力学最小;此外,该研究还观察到瓣环中点随着心动周期出现垂直平移运动,收缩末期与舒张末期间的垂直平移距离是(11.3±3.7) mm。由于压力或容量负荷的改变,右室扩张,从而使瓣环扩大、瓣叶受到牵拉造成的反流多是功能性三尖瓣反流[29]。Ring 等[30]对比正常和右室扩张的三尖瓣环发现,右室扩张组的左右径明显增大,偏心率(前后径和左右径的比值)更小,这种瓣环动力学的改变可能是功能性三尖瓣反流产生的原因之一。Utsunomiya 等[31]在 Af 引起 FMR 的研究中也发现三尖瓣环扩张,并且瓣环的收缩减弱。RT 3D-TEE 不仅有助于反流原因的探索,而且对于评估成形术对瓣环的影响也有帮助。Nishi 等[32]对三尖瓣成形前和成形后进行对比研究发现,成形术后三尖瓣环周长、面积和高度明显减低,而偏心率明显增大;不同的成形环对瓣环的改变也不尽相同,韧性环组瓣环高度更低,而刚性环组偏心率更低,但两种成形环均有助于减轻反流。Dreyfus 等[33]通过一组对比研究说明,2D-TTE 相比 RT 3D-TEE 明显低估了三尖瓣环径,与手术结果仅有轻度相关性,且重复性较差,因此 RT 3D-TEE 是评估三尖瓣更好的选择。

4 肺动脉瓣病变

2016 年 Hadeed 等[34]应用 3D-TTE 评估了 29 例法洛四联症患儿肺动脉瓣的形态,并进行肺动脉瓣环径的测量。Kemaloglu 等[35]在 2016 年应用 RT 3D-TEE 对 16 例肺动脉瓣狭窄的成年患者进行评估,该研究发现,3D-TEE 测量的最大瓣环径较 2D-TEE 明显增大,因此 RT 3D-TEE 应该作为常规评估的补充。

综上,RT 3D-TEE 可更为形象、立体地显示心脏瓣膜结构,且 RT 3D-TEE 的准确定量评价能为心脏瓣膜病的手术决策、术中监测及术后随访提供更多、更具有针对性的精确信息。

参 考 文 献

[1] Prempeh ABA, Scherman J, Swanevelder JL. Transesophageal echocardiography in minimally invasive cardiac surgery[J]. Curr Opin Anaesthesiol, 2020, 33(1):83-91.

[2] Karamnov S, Burbano-Vera N, Huang CC, et al. Echocardiographic assessment of mitral stenosis orifice area: a comparison of a novel three-dimensional method versus conventional techniques[J]. Anesth Analg, 2017, 125(23):774-780.

[3] Uygur B, Celik O, Ustabasioglu FE, et al. Three-dimensional transesophageal echocardiography vs cardiac magnetic resonance in the assessment of planimetric mitral valve area in rheumatic mitral stenosis[J]. Echocardiography, 2018, 35(10):1621-1625.

[4] Kang WS, Ko SM, Lee Y, et al. Three-dimensional transesophageal echocardiography for determination of mitral valve area after mitral valve repair surgery for mitral stenosis[J]. J Cardiovasc Surg(Torino), 2016, 57(4):606-614.

[5] 亢玉,张庆. 二尖瓣瓣叶在功能性二尖瓣反流发生机制中的角色[J]. 心血管病学进展,2016,27(4):376-379.

[6] Kagiyama N, Toki M, Hara M, et al. Efficacy and accuracy of novel automated mitral valve quantification: three-dimensional transesophageal echocardiographic study[J]. Echocardiography, 2016, 33(5):756-763.

[7] Sun X, Jiang Y, Huang G, et al. Three-dimensional mitral valve structure in predicting moderate ischemic mitral regurgitation improvement after coronary artery bypass grafting[J]. J Thorac Cardiovasc Surg, 2019, 157(5):1795-1803.

[8] van Wijngaarden SE, Kamperidis V, Regeer MV, et al. Three-dimensional assessment of mitral valve annulus dynamics and impact on quantification of mitral regurgitation[J]. Eur Heart J Cardiovasc Imaging, 2018, 19(2), 176-184.

[9] Apor A, Nagy AI, Kovács A, et al. Three-dimensional dynamic morphology of the mitral valve in different forms of mitral valve prolapse—Potential implications for annuloplasty ring selection[J]. Cardiovasc Ultrasound, 2016, 14(1):32-37.

[10] Mahmood F, Knio ZO, Yeh L, et al. Regional heterogeneity in the mitral valve apparatus in patients with ischemic mitral regurgitation[J]. Ann Thorac Surg, 2017, 103(4):1171-1177.

[11] Kagiyama N, Hayashida A, Toki M, et al. Insufficient leaflet remodeling in patients with atrial fibrillation: association with the severity of mitral regurgitation[J]. Circ Cardiovasc Imaging, 2017, 10(3):1-8.

[12] Ito K, Abe Y, Takahashi Y, et al. Mechanism of atrial functional mitral regurgitation in patients with atrial fibrillation: a study using three-dimensional transesophageal echocardiography[J]. J Cardiol, 2017, 70(6):584-590.

[13] Cobey FC, Ferreira R, Ursprung WW, et al. A novel approach to assess the three-dimensional anatomy of a mitral valve regurgitant jet orifice[J]. J Cardiothorac Vasc Anesth, 2016, 31(1):169-173.

[14] Poelaert JI, Bouchez S. Perioperative echocardiographic assessment of mitral valve regurgitation: a comprehensive review[J]. Eur J Cardiothorac Surg, 2016, 50(5):801-812.

[15] Berdejo J, Shiota M, Mihara H, et al. Vena contracta analysis by color Doppler three-dimensional transesophageal echocardiography shows geometrical differences between prolapse and pseudoprolapse in eccentric mitral regurgitation[J]. Echocardiography, 2017, 34(5):683-689.

[16] Khan F, Winkel M, Ong G, et al. Percutaneous mitral edge-to-edge repair: state of the art and a glimpse to the future[J]. Front Cardiovasc Med, 2019, 6(122):

1-7.

[17] Herbrand T, Eschenhagen S, Zeus T, et al. Acute reverse annular remodeling during MitraClip therapy predicts improved clinical outcome in heart failure patients: a 3D echocardiography study[J]. Eur J Med Res, 2017, 22(1): 1-11.

[18] Ryomoto M, Mitsuno M, Yamamura M, et al. Physiological mitral annular dynamics preserved after ring annuloplasty in mid-term period[J]. Gen Thorac Cardiovasc Surg, 2017, 65(11): 627-632.

[19] Machida T, Izumo M, Suzuki K, et al. Value of anatomical aortic valve area using real-time three-dimensional transoesophageal echocardiography in patients with aortic stenosis: a comparison between tricuspid and bicuspid aortic valves[J]. Eur Heart J Cardiovasc Imaging, 2015, 16(10): 1120-1128.

[20] Alskaf E, Kardos A. The mystery of defining aortic valve area: what have we learnt from three-dimensional imaging modalities? [J]. Echocardiography, 2018, 16(3): 130-138.

[21] Zhang M, Wan L, Liu K, et al. Aortic roots assessment by an automated three-dimensional transesophageal echocardiography: an intra-individual comparison [J]. Int J Cardiovasc Imaging, 2019, 35(11): 2029-2036.

[22] García-Martín A, Lázaro-Rivera C, Fernández-Golfín C, et al. Accuracy and reproducibility of novel echocardiographic three-dimensional automated software for the assessment of the aortic root in candidates for thanscatheter aortic valve replacement[J]. Eur Heart J Cardiovasc Imaging, 2016, 17(7), 772-778.

[23] Tamborini G, Fusini L, Gripari P, et al. Feasibility and accuracy of 3DTEE versus CT for the evaluation of aortic valve annulus to left main ostium distance before transcatheter aortic valve implantation[J]. JACC Cardiovasc Imaging, 2012, 5(6): 579-588.

[24] Gripari P, Ewe SH, Fusini L, et al. Intraoperative 2D and 3D transoesophageal echocardiographic predictors of aortic regurgitation after transcatheter aortic valve implantation[J]. Heart, 2012, 98(16): 1229-1236.

[25] Pibarot P, Magne J, Leipsic J, et al. Imaging for predicting and assessing prosthesis-patient mismatch after aortic valve replacement[J]. JACC Cardiovasc Imaging, 2019, 12(1): 149-162.

[26] Sohmer B, Jafar R, Patel P, et al. Aortic valve cusp coaptation surface area using 3-dimensional transesophageal echocardiography correlates with severity of aortic valve insufficiency[J]. J Cardiothorac Vasc Anesth, 2018, 32(1): 344-351.

[27] Badano LP, Hahn R, Rodríguez-Zanella H, et al. Morphological assessment of the tricuspid apparatus and grading regurgitation severity in patients with functional tricuspid regurgitation: thinking outside the box[J]. JACC Cardiovasc Imaging, 2019, 12(4): 652-664.

[28] Owais K, Taylor CE, Jiang L, et al. Tricuspid annulus: a three-dimensional deconstruction and reconstruction[J]. Ann Thorac Surg, 2014, 98(5): 1536-1543.

[29] Ancona F, Stella S, Taramasso M, et al. Multimodality imaging of the tricuspid valve with implication for percutaneous repair approaches[J]. Heart, 2017, 103(14): 1073-1081.

[30] Ring L, Rana BS, Kydd A, et al. Dynamics of the tricuspid valve annulus in normal and dilated right hearts: a three-dimensional transoesophageal echocardiography study[J]. Eur Heart J Cardiovasc Imaging, 2012, 13(9): 756-762.

[31] Utsunomiya H, Itabashi Y, Mihara H, et al. Functional tricuspid regurgitation caused by chronic atrial fibrillation: a real-time 3-dimensional transesophageal echocardiography study[J]. Circ Cardiovasc Imaging, 2017, 10(1): 1-15.

[32] Nishi H, Toda K, Miyagawa S, et al. Tricuspid annular dynamics before and after tricuspid annuloplasty-three-dimensional transesophageal echocardiography[J]. Circ J, 2015, 79(4): 873-879.

[33] Dreyfus J, Durandviel G, Raffoul R, et al. Comparison of 2-dimensional, 3-dimensional, and surgical measurements of the tricuspid annulus size clinical implications[J]. Circ Cardiovasc Imaging, 2015, 8(7): 1-10.

[34] Hadeed K, Hascoët S, Amadieu R, et al. 3D transthoracic echocardiography to assess pulmonary valve morphology and annulus size in patients with Tetralogy of Fallot[J]. Arch Cardiovasc Dis, 2016, 109(2): 87-95.

[35] Kemaloglu Öz T, Özpamuk Karadeniz F, Akyüz Ş, et al. The advantages of live/real time three-dimensional transesophageal echocardiography during assessments of pulmonary stenosis[J]. Int J Cardiovasc Imaging, 2016, 32(4): 573-582.

收稿时间：2020-03-11

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