经导管主动脉瓣置换术后并发症的防治研究进展*

周道 戚鑫瑞 朱齐丰 戴晗怡 刘先宝* 王建安
浙江大学医学院附属第二医院心血管内科,浙江杭州 310000

摘要 根据国际最新心脏瓣膜病管理指南,经导管主动脉瓣置换术(TAVR)是重度主动脉瓣狭窄的主要治疗方式。随着 TAVR 手术应用于更多人群、瓣膜研究学术联盟共识-3(VARC-3)对临床事件的重新定义,TAVR 术后的并发症需要得到更多的关注,因此,本文就血管并发症、冠脉阻塞、新发传导阻滞、脑卒中和脑保护装置、瓣叶血栓和瓣叶衰败等并发症的研究进展作一综述,以增加临床工作者对 TAVR 术后并发症的认识。

关键词 导管主动脉瓣置换术; 并发症; 临床事件; 瓣膜研究学术联盟共识-3
中图分类号 R542.5;R654.2 **文献标识码** A DOI 10.11768/nkjwzzzz20210602

Advances in prevention and treatment of complications after transcatheter aortic valve replacement *ZHOU Dao, QI Xin-rui, ZHU Qi-feng, DAI Han-yi, LIU Xian-bao*, WANG Jian-an. Department of Cardiology, Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou 310000, China*
Corresponding author: LIU Xian-bao, E-mail: liuxb@zju.edu.cn

Abstract Transcatheter aortic valve replacement (TAVR) is an important treatment for severe aortic stenosis according to the updated guideline of valvular heart disease. As Valve Academic Research Consortium-3 has updated the definition of the clinical events and there would be more patients receiving TAVR in the future, clinicians should pay more attention to complications after TAVR. This study reviews the advances and frontiers in TAVR´s complications such as vascular complications, coronary obstruction, new-onset conduction disturbance, stroke and cerebral protection device, valve thrombosis, structure valve deterioration and bioprosthetic valve failure etc, in order to increase the understanding of complications after TAVR.

Key words Transcatheter aortic valve replacement; Complications; Clinical events; Valve academic research consortium-3

主动脉瓣狭窄(aortic stenosis,AS)是严重威胁老年人健康的一种常见疾病,重度 AS 患者一旦出现相应临床症状,往往预后极差,主动脉瓣置换手术是其主要治疗方式。经导管主动脉瓣置换术(transcatheter aortic valve replacement,TAVR)作为一种创伤极小的创新性技术,自 2002 年初次临床应用以来得到快速发展[1];根据胸外科医师协会(Society of Thoracic Surgeons, STS)数据库的数据,目前行 TAVR 治疗的重度 AS 患者人数已经超过接受外科主动脉瓣置换(surgical aortic valve replacement, SAVR)的患者[2]。随着 TAVR 应用于更多人群,TAVR 术后并发症的关注度日益提升,且近期瓣膜研究学术联盟共识-3(Valve Academic Research Consortium-3,VARC-3)对部分并发症进行了重新定义[3],因此,本文就 TAVR 术后并发症的研究热点及进展进行概述。

血管并发症

TAVR 术后血管并发症发生率约为 6.8% ~ 32.8%[4~6]。根据 PARTNER 1 研究数据,严重血管并发症的发生率为 15.3%,包括血管夹层(62.8%)、穿孔(31.3%)和穿刺部位血肿(22.9%),与更多的 30 d 大出血、输血和肾衰竭发生率相关,是1 年死亡率的独立预测因子,而轻微血管并发症(11.9%)不影响临床预后[4]。外周血管并发症与血管穿刺、闭合操作密切相关, Potluri 等[7]的一项倾向性匹配研究(propensity-score matched study,PSM)提示,超声引导下穿刺的血管并发症发生率较造影引导更低(7.9% *vs* 14.2%)。血管闭合阶段,血管缝合器闭合是目前使用最广泛的方法,外科手术闭合亦较为常用。总体来说两者具有相似的血管并发症风险,然而在患有外周血管疾病的女性中手术闭合似乎更优[8]。此外,血管并发症的危险因素还包括较大的鞘管与穿刺股动脉直径比值、女性、体重指数(body mass index,BMI)较大等[9,10]。随着输送鞘管直径的缩小、各中心经验的积累以及更多低危患者接受 TAVR 手术,2011-2016 年血管并发症发生率由 15% ~ 20% 下降至约

*基金项目:浙江省科技厅重点研发计划(2021C03097,2018C03084)
*通信作者:刘先宝,E-mail:liuxb@zju.edu.cn,浙江省杭州市上城区解放路 88 号

7%[11],在最近的低危患者随机对照试验(randomized controlled trial,RCT)中严重血管并发症的发生率仅 2.2% ~3.8%[6,12]。

瓣膜位置异常

瓣膜位置异常包括瓣膜移位(valve migration)、瓣膜栓塞(valve embolization)、异位瓣膜植入(ectopic valve implantation)。在瓣膜释放的过程中可能出现瓣膜上弹或下滑,称为瓣膜移位。若瓣膜释放后彻底脱离瓣环弹入主动脉或心室即为瓣膜栓塞,常需要紧急转外科手术。一项包括 29 636 患者的研究显示,瓣膜移位和栓塞的发生率为 0.92%,其中 79.5% 进入升主动脉,20.5% 进入左心室,与显著增加的 30 d 死亡率和脑卒中发生率有关[13]。若瓣膜最终释放位置位于主动脉根部以外区域(如主动脉弓、腹主动脉)称为异位瓣膜植入,小样本回顾性研究尚未发现异位瓣膜植入对预后的影响[14,15]。随着新一代可回收器械在临床上更加广泛的使用,可以预料瓣膜位置异常导致的瓣中瓣植入和紧急转外科的发生率将明显降低。

冠脉阻塞

冠脉阻塞是近来倍受重视的严重并发症,瓣膜支架、原生瓣叶和瓣叶钙化均可阻塞冠脉开口导致冠脉闭塞。冠脉阻塞发生率较低,一般 <1%,由于左冠开口常较右冠更低,左冠闭塞相对较为多见[16]。Ribeiro 等[16]发现,冠脉开口距瓣环的高度 <12 mm、冠脉窦最大处直径 <30 mm 是冠脉阻塞的高危因素,同时具备这两种高危因素的患者中有 86.7% 发生了冠脉阻塞。他们还发现在生物瓣膜衰败行瓣中瓣 TAVR 手术的患者中冠脉阻塞的发生率相对较高,约 2.3%,其中带有金属支架的衰败瓣膜的患者行瓣中瓣治疗更容易发生冠脉阻塞[17]。通过在重建 CT 冠脉开口层面上测量衰败瓣膜的金属支架距离冠脉开口的距离(valve to coronary ostium distance,VTC)可以评价行瓣中瓣 TAVR 患者的冠脉风险,VTC <4 mm 提示存在较高的冠脉阻塞风险[17]。此外,球囊预扩张时关注冠脉显影也是一种判断冠脉闭塞风险和是否需要冠脉保护的有效方法。针对冠脉阻塞高风险患者,可考虑行烟囱支架、导丝保护和生物瓣膜或自体主动脉瓣扇形撕裂预防医源性冠状动脉阻塞技术(bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction,BASILICA)[18]来预防冠脉阻塞的发生[19]。约 0.2% 的患者会出现 TAVR 术后迟发性冠脉阻塞,其中 47.4% 发生于 24 h 内,36.8% 发生在 TAVR 手术 7 d 后[20]。对于 TAVR 术后患者,除原生瓣膜可对冠脉再介入造成阻碍,植入的瓣膜支架结构也会进一步提升冠脉再介入的手术难度。目前有研究提示可以通过术中特殊的瓣膜植入对位技巧来降低再介入难度[21],但仍有待深入研究更优解决方案。

循环崩溃

主动脉根部破裂、心脏穿孔、冠脉阻塞、瓣膜移位等并发症均可导致循环崩溃,常需紧急转外科。一项多中心研究发现,27 760 例患者术中紧急转外科的发生率为 0.76%,而 72 h 死亡率达 34.6%[22]。对于病情危重患者,术中球囊扩张、导丝跨瓣、快速起搏、瓣膜释放等各环节均可出现血流动力学不稳定,此时快速平稳地释放瓣膜和同步心肺复苏是处理循环崩溃的关键。循环辅助装置如体外膜肺氧合(extracorporeal membrane oxygenation,ECMO)、左室辅助装置及主动脉球囊反搏等也是挽救生命的重要手段。有文献提示对于危重患者术前预防性使用循环辅助装置较术中紧急使用预后更好[23],但其使用时机及确切疗效尚待大样本研究进一步探索。

脑卒中

TAVR 术后脑卒中在主要 RCT 研究中发生率为 0.6% ~5.4%[24],约 1/3 脑卒中发生在 TAVI 手术当天,80% 发生在 TAVI 后的第 1 周内,一旦发生显性卒中,30 d 死亡风险较未发生卒中患者高 6 倍[25]。无症状性脑卒中表现为术后头颅 DWI 上的新发高信号梗死病灶而无相应的临床症状。一项 2021 年发表在欧洲心脏病学杂志的荟萃分析显示,超过 70% 患者术后存在至少 1 个新发高信号病灶,且高信号病灶个数与认知功能的下降相关[26],而 VARC-3 指南同样较 VARC-2 增加了隐性中枢神经系统损伤的评价[3],提示术后的无症状性卒中同样需要得到更多的重视。

目前认为,合并糖尿病、肾功能不全、球囊预扩张、选择非经股动脉入路等多项因素与术后脑卒中相关[26,27],而 TAVR 术中的栓子脱落形成脑栓塞是患者术后发生缺血性脑卒中的主要病因,Schmidt 等[28]使用脑保护装置(cerebral protection device,CPD)的研究发现,几乎所有的患者均可以捕捉到碎片,栓子的病理类型包括主动脉壁、瓣叶组织、急性

血栓、钙化等,因此,使用脑保护装置可能是减少脑卒中发生的可行措施。一项荟萃 SENTINEL US IDE、CLEAN-TAVI、SENTINEL-UIm 研究的 PSM 研究提示使用 CPD 可减少 65% 的围术期脑卒中发生[29]。此外,一项对国家住院样本数据库 36 220 例患者进行 PSM 研究同样发现使用 CPD 组的缺血性卒中发生率显著较对照组更低(1% *vs* 3.8%)[30]。然而 REFLECT 系列、DEFLECT 系列及 CLEAN-TAVI 等 RCT 研究尽管揭示了 CPD 可减少 DWI 上梗死病灶数量和容积,但未能证实 CPD 与临床脑卒中事件间的显著性关联[31~33],这可能与样本量、脑卒中的发生率低有关。此外,受经济因素、脑卒中发生率、脑保护操作带来的额外风险等因素影响,脑保护装置在 TAVR 人群的适应证仍需进一步探索。

心律失常

传导阻滞 由于心脏传导系统在室间隔膜部、瓣膜锚定区域附近走行,术中操作直接损伤、瓣膜压迫、局部水肿、炎症均可引起左束支传导阻滞(left bundle branch block, LBBB)、高度房室传导阻滞(high-grade atrioventricular block, HAVB),完全性房室传导阻滞(complete heart block, CHB)、最终导致患者需要行永久起搏器植入术(permanent pacemaker implantation, PPMI)。目前认为,术后新发完全性左束支传导阻滞(complete LBBB, CLBBB)或 PPMI 与更高的 1 年全因死亡率、心力衰竭再入院率及左室功能恢复不良相关[34]。术前合并传导阻滞如右束支传导阻滞、室间隔膜部短、左室流出道传导束区域钙化是术后 HAVB、PPMI 的危险因素[35]。此外,手术操作如瓣膜植入深、瓣膜尺寸过大、选择机械膨胀瓣膜或自膨胀瓣膜与新发传导阻滞风险增加密切相关[36],因而导致出院前 CLBBB(10.5% ~ 52.3%)和 PPMI(5.9% ~32.0%)的发生率在不同的研究中有较大差异[34]。由于严重的传导阻滞可能对早期出院的患者带来较高的恶性事件风险,2019 年发表在美国心脏病学杂志的专家共识系统地评价了 TAVR 术后传导阻滞的预测因素和管理方案[37],并针对传导阻滞进行了危险分层:①可早期出院患者;②HAVB 高危患者;③需要起搏器植入患者。这种分层的有效性在一项纳入 1 439 例患者的研究中得到了证实,根据危险分层的 3 组分别有 2.7%、41%、100% 的患者在 30 d 内接受了 PPMI 治疗[38]。此外,除常规的心电监测手段之外,可提供长期心电监控的植入式设备或便携可穿戴设备在 TAVR 术后有传导阻滞风险的患者中也被证实了其临床价值[39, 40]。

心房颤动 TAVR 术前约有 1/3 以上的患者合并心房颤动,而术后可有 17.5% 的患者新发房颤,累计共有近 50% 的 TAVR 患者可在术后合并心房颤动[41],与短期和长期的死亡、心力衰竭再入院、脑卒中及出血事件密切相关[42, 43]。高龄、心功能差、显著扩大的左心房、脑血管疾病史和选择非股动脉入路、术中血流动力学不稳定等多项因素与新发房颤的风险增高有关[42],而新发房颤较无房颤和术前合并房颤的患者脑卒中的风险均显著增加[43],因此 TAVR 术后房颤的抗栓管理是目前该领域的热点话题。POPular TAVI 研究发现,有抗凝指征的患者术后单用口服抗凝药优于抗凝联合氯吡格雷治疗[44],而 2021ESC/EACTS 指南同样推荐有抗凝指征的患者术后单用口服抗凝药[45]。目前合并房颤的 TAVR 患者在房颤复律和节律控制、左心耳封堵治疗等方面尚无足够的证据。Watch-TAVI 是一项进行中的多中心 RCT 研究,对 TAVR 患者同时行Watchman ® 左心耳封堵治疗与 TAVR 联合药物治疗进行疗效比较,有望为合并房颤的 TAVR 患者管理提供更多依据。

瓣膜功能异常

VARC-3 中将瓣膜功能异常定义成结构性瓣膜退变(structural valve deterioration, SVD)、瓣叶血栓、非结构性瓣膜功能异常以及感染性心内膜炎四种类型[3]。随着 TAVR 适应证拓展向低危人群,TAVR 术后瓣膜的长期耐久性(主要是亚临床瓣叶血栓和 SVD)受到了广泛关注。亚临床瓣叶血栓目前主要通过 CT 影像上的瓣叶增厚(hypo-attenuated leaflet thickening, HALT)和瓣叶活动度减退(reduced leaflet motion, RELM)来评价。Chakravarty 等[46]发现,在 TAVR 术后中位时间 58d 行 CT 检查的患者中,13% 的患者出现了亚临床瓣叶血栓,与短暂性脑缺血发作事件增加相关。GALILEO 和 ATLANTIS 的 4D-MDCT 子研究提示抗凝治疗可以减少 HALT 和 RELM 的发生[47, 48]。此外,有文献提示瓣叶血栓形成后改用抗凝治疗是一种有效的治疗方式[46]。

根据定义,SVD 是因植入瓣叶结构发生改变导致出现明显的主动脉瓣流速增快、跨瓣压差升高或者新发中度以上的瓣中反流。在 FRANCE-2 研究中,5 年重度 SVD 和中度/重度 SVD 的发生率分别为 2.5% 和 13.3%[49]。PARTNER 2 研究 5 年随访结果发现,TAVR 的第一代球囊扩张瓣膜 SVD 和生

物瓣膜衰败发生率显著高于外科瓣膜置换,而在第三代球囊扩张瓣膜中则没有差异[50]。而自膨胀瓣膜的 NOTION 研究提示, 8 年随访期间 TAVR 出现 SVD 的风险低于 SAVR(13.9% *vs* 28.3%)[51]。Long 等[52]一项纳入 10 031 例患者的荟萃研究发现,TAVR 术后 1 年内 SVD 发生率为 4.93%,而在超过 5 年的长期随访过程中,8.97% 的患者会发生 SVD。同时,该研究发现抗凝药物的使用可以减少 SVD 的发生[52]。

其 他

除前述外,TAVR 术后也可出现瓣周漏、急性肾损伤等并发症。其中瓣周漏是 TAVR 术后常见的并发症,在早期的 PARTNER I 研究中,30d 中重度瓣周漏的发生率为 12.2%[53],有荟萃分析提示术后合并中重度瓣周漏患者 1 年死亡风险升高 2.1 倍[54]。随着手术策略以及新一代器械裙边设计的进步,在低危 RCT 研究里中重度瓣周漏的发生率仅 0.8% ~3.5%[6,12]。TAVR 术后急性肾损伤亦较为常见,与术中造影剂使用、再灌注损伤相关,缩短手术时间、减少对比剂的使用可能有助于降低其发生率。而对于 TAVR 术后生存情况,在 PARTNER 系列研究中,外科手术高危、中危的患者 TAVR 术后 30 d 全因死亡率分别为 3.4% 和 3.9%[53, 55],5 年全因死亡率分别为 67.8% 和 46.0%[56, 57];在 PARTNER 3 的低危患者研究中 TAVR 术后 30d 死亡率仅 0.4%[6];而在随访已达 8 年针对低危人群的 NOTION 研究中,TAVR 术后 8 年的存活率为 51.8%[51]。TAVR 术后长期随访的证据正逐渐积累,目前研究提示 TAVR 术后长期生存率均与外科瓣膜置换手术相似,期待 PARTNER 3 和 Evolut Low Risk 研究的 5 年随访结果为 TAVR 提供更多依据。

结 语

目前全国各大中心手术量逐年增加,更加精细化的术前评估、不断积累的手术经验以及新一代器械的发展使一些常见并发症如瓣周漏、血管并发症的发生率逐年下降,然而随着适应证拓展至低危人群,冠脉再介入难度、瓣膜耐久性受到了广泛的关注,TAVR 术后早期出院的理念亦对术后传导阻滞的预测识别和管理提出了更高的要求。此外,隐性脑卒中和认知功能、脑保护装置依旧是当下研究的热点。相信随着对 TAVR 术后并发症更加深入的探索,TAVR 可以在更多中心成为一项安全的常规技术。

参 考 文 献

1 Cribier A, Eltchaninoff H, Bash A, et al. Percutaneous transcatheter implantation of an aortic valve prosthesis for calcific aortic stenosis: first human case description[J]. Circulation, 2002, 106(24): 3006-3008.
2 Bowdish ME, D'Agostino RS, Thourani VH, et al. STS adult cardiac surgery database: 2021 update on outcomes quality and research[J]. Ann Thorac Surg, 2021, 111(6): 1770-1780.
3 Généreux P, Piazza N, Alu MC, et al. Valve academic research consortium 3: updated endpoint definitions for aortic valve clinical research[J]. J Am Coll Cardiol, 2021, 77(21): 2717-2746.
4 Généreux P, Webb JG, Svensson LG, et al. Vascular complications after transcatheter aortic valve replacement: insights from the PARTNER (Placement of AoRTic TraNscathetER Valve) trial[J]. J Am Coll Cardiol, 2012, 60(12): 1043-1052.
5 Sherwood MW, Xiang K, Matsouaka R, et al. Incidence temporal trends and associated outcomes of vascular and bleeding complications in patients undergoing transfemoral transcatheter aortic valve replacement: insights from the society of thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapies Registry[J]. Circ Cardiovasc Interv, 2020, 13(1): e8227.
6 Mack MJ, Leon MB, Thourani VH, et al. Transcatheter aortic-valve replacement with a balloon-expandable valve in low-risk patients[J]. N Engl J Med, 2019, 380(18): 1695-1705.
7 Potluri SP, Hamandi M, Basra SS, et al. Comparison of frequency of vascular complications with ultrasound-guided versus fluroscopic roadmap-guided femoral arterial access in patients who underwent transcatheter aortic valve implantation[J]. Am J Cardiol, 2020, 132: 93-99.
8 Eckner D, Pollari F, Santarpino G, et al. Comparison between surgical access and percutaneous closure device in 787 patients undergoing transcatheter aortic valve replacement[J]. J Clin Med, 2021, 10(7): 1344.
9 Berti S, Bartorelli AL, Koni E, et al. Impact of high body mass index on vascular and bleeding complications after transcatheter aortic valve implantation[J]. Am J Cardiol, 2021, 155: 86-95.
10 van Kesteren F, van Mourik MS, Vendrik J, et al. Incidence predictors and Impact of vascular complications after transfemoral transcatheter aortic valve implantation with the SAPIEN 3 prosthesis[J]. Am J Cardiol, 2018, 121(10): 1231-1238.
11 Sherwood MW, Xiang K, Matsouaka R, et al. Incidence temporal trends and associated outcomes of vascular and bleeding complications in patients undergoing transfemoral transcatheter aortic valve replacement: insights from the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapies Registry[J]. Circ Cardiovasc Interv, 2020, 13(1): e8227.
12 Popma JJ, Deeb GM, Yakubov SJ, et al. Transcatheter aortic-valve replacement with a self-expanding valve in low-risk patients[J]. N Engl J Med, 2019, 380(18): 1706-1715.
13 Kim WK, Schäfer U, Tchetche D, et al. Incidence and outcome of peri-procedural transcatheter heart valve embolization and migration: the TRAVEL registry (TranscatheteR HeArt Valve EmboLization and Migration)[J]. Eur Heart J, 2019, 40(38): 3156-3165.
14 Tay EL, Gurvitch R, Wijeysinghe N, et al. Outcome of patients after transcatheter aortic valve embolization[J]. JACC Cardiovasc Interv, 2011, 4(2): 228-234.
15 Gerckens U, Latsios G, Mueller R, et al. Procedural and mid-term results in patients with aortic stenosis treated with implantation of 2 (in-series) CoreValve prostheses in 1 procedure[J]. JACC Cardiovasc Interv, 2010, 3(2): 244-250.
16 Ribeiro HB, Webb JG, Makkar RR, et al. Predictive factors management, and clinical outcomes of coronary obstruction following transcatheter aortic valve implantation: insights from a large multicenter registry[J]. J Am Coll Cardiol, 2013, 62(17): 1552-1562.
17 Ribeiro HB, Rodés-Cabau J, Blanke P, et al. Incidence predictors and clinical outcomes of coronary obstruction following transcatheter aortic valve replacement for degenerative bioprosthetic surgical valves: insights from the VIVID registry[J]. Eur Heart J, 2018, 39(8): 687-695.
18 Khan JM, Babaliaros VC, Greenbaum AB, et al. Preventing coronary obstruction during transcatheter aortic valve replacement: results from the multicenter international BASILICA registry[J]. JACC Cardiovasc Interv, 2021, 14(9): 941-948.

19 Shatila W, Krajcer Z. A cardiologist's nightmare: coronary obstruction during transcatheter aortic valve implantation: How to identify patients at highest risk for this complication[J]. Catheter Cardiovasc Interv, 2017, 90(7): 1198-1199.

20 Jabbour RJ, Tanaka A, Finkelstein A, et al. Delayed coronary obstruction after transcatheter aortic valve replacement[J]. J Am Coll Cardiol, 2018, 71(14): 1513-1524.

21 Tang G, Zaid S, Fuchs A, et al. Alignment of transcatheter aortic-valve neo-commissures (ALIGN TAVR): impact on final valve orientation and coronary artery overlap[J]. JACC Cardiovasc Interv, 2020, 13(9): 1030-1042.

22 Eggebrecht H, Vaquerizo B, Moris C, et al. Incidence and outcomes of emergent cardiac surgery during transfemoral transcatheter aortic valve implantation (TAVI): insights from the European Registry on Emergent Cardiac Surgery during TAVI (EuRECS-TAVI)[J]. Eur Heart J, 2018, 39(8): 676-684.

23 Seco M, Forrest P, Jackson SA, et al. Extracorporeal membrane oxygenation for very high-risk transcatheter aortic valve implantation[J]. Heart Lung Circ, 2014, 23(10): 957-962.

24 Matsuda Y, Nai FL, Giacoppo D, et al. Association between surgical risk and 30-day stroke after transcatheter versus surgical aortic valve replacement: a systematic review and meta-analysis[J]. Catheter Cardiovasc Interv, 2021, 97(4): E536-E543.

25 Vlastra W, Jimenez-Quevedo P, Tchétché D, et al. Predictors incidence and outcomes of patients undergoing transfemoral transcatheter aortic valve implantation complicated by stroke[J]. Circ Cardiovasc Interv, 2019, 12(3): e7546.

26 Woldendorp K, Indja B, Bannon PG, et al. Silent brain infarcts and early cognitive outcomes after transcatheter aortic valve implantation: a systematic review and meta-analysis[J]. Eur Heart J, 2021, 42(10): 1004-1015.

27 Faroux L, Junquera L, Mohammadi S, et al. Femoral versus nonfemoral subclavian/carotid arterial access route for transcatheter aortic valve replacement: a systematic review and meta-analysis[J]. J Am Heart Assoc, 2020, 9(19): e17460.

28 Schmidt T, Leon MB, Mehran R, et al. Debris heterogeneity across different valve types captured by a cerebral protection system during transcatheter aortic valve replacement[J]. JACC Cardiovasc Interv, 2018, 11(13): 1262-1273.

29 Seeger J, Kapadia SR, Kodali S, et al. Rate of peri-procedural stroke observed with cerebral embolic protection during transcatheter aortic valve replacement: a patient-level propensity-matched analysis[J]. Eur Heart J, 2019, 40(17): 1334-1340.

30 Megaly M, Sorajja P, Cavalcante JL, et al. Ischemic stroke with cerebral protection system during transcatheter aortic valve replacement[J]. JACC Cardiovasc Interv, 2020, 13(18): 2149-2155.

31 Haussig S, Mangner N, Dwyer MG, et al. Effect of a cerebral protection device on brain lesions following transcatheter aortic valve implantation in patients with severe aortic stenosis: the CLEAN-TAVI randomized clinical Trial[J]. JAMA, 2016, 316(6): 592-601.

32 Lansky AJ, Schofer J, Tchetche D, et al. A prospective randomized evaluation of the TriGuard™ HDH embolic DEFLECTion device during transcatheter aortic valve implantation: results from the DEFLECT III trial[J]. Eur Heart J, 2015, 36(31): 2070-2078.

33 Nazif TM, Moses J, Sharma R, et al. Randomized evaluation of triGuard 3 cerebral embolic protection after transcatheter aortic valve replacement: REFLECT II[J]. JACC Cardiovasc Interv, 2021, 14(5): 515-527.

34 Faroux L, Chen S, Muntané-Carol G, et al. Clinical impact of conduction disturbances in transcatheter aortic valve replacement recipients: a systematic review and meta-analysis[J]. Eur Heart J, 2020, 41(29): 2771-2781.

35 Maeno Y, Abramowitz Y, Kawamori H, et al. A Highly predictive risk model for pacemaker implantation after TAVR[J]. JACC Cardiovasc Imaging, 2017, 10(10 Pt A): 1139-1147.

36 Auffret V, Puri R, Urena M, et al. Conduction disturbances after transcatheter aortic valve replacement: current status and future perspectives[J]. Circulation, 2017, 136(11): 1049-1069.

37 Rodés-Cabau J, Ellenbogen KA, Krahn AD, et al. Management of conduction disturbances associated with transcatheter aortic valve replacement: JACC Scientific Expert Panel[J]. J Am Coll Cardiol, 2019, 74(8): 1086-1106.

38 Malebranche D, Bartkowiak J, Ryffel C, et al. Validation of the 2019 expert consensus algorithm for the management of conduction disturbances after TAVR[J]. JACC Cardiovasc Interv, 2021, 14(9): 981-991.

39 Liu X, Fan J, Guo Y, et al. Smart watch measured conduction disturbance after transcatheter aortic valve replacement[J]. J Am Coll Cardiol, 2021, 77(18): 1136.

40 Rodés-Cabau J, Urena M, Nombela-Franco L, et al. Arrhythmic burden as determined by ambulatory continuous cardiac monitoring in patients with New-Onset persistent left bundle branch block following transcatheter aortic valve replacement: the MARE study[J]. JACC Cardiovasc Interv, 2018, 11(15): 1495-1505.

41 Sannino A, Gargiulo G, Schiattarella GG, et al. A meta-analysis of the impact of pre-existing and new-onset atrial fibrillation on clinical outcomes in patients undergoing transcatheter aortic valve implantation[J]. EuroIntervention, 2016, 12(8): e1047-e1056.

42 Tarantini G, Mojoli M, Urena M, et al. Atrial fibrillation in patients undergoing transcatheter aortic valve implantation: epidemiology, timing, predictors, and outcome[J]. Eur Heart J, 2017, 38(17): 1285-1293.

43 Mentias A, Saad M, Girotra S, et al. Impact of pre-existing and new-onset atrial fibrillation on outcomes after transcatheter aortic valve replacement[J]. JACC Cardiovasc Interv, 2019, 12(21): 2119-2129.

44 Nijenhuis VJ, Brouwer J, Delewi R, et al. Anticoagulation with or without clopidogrel after transcatheter aortic-valve implantation[J]. N Engl J Med, 2020, 382(18): 1696-1707.

45 Vahanian A, Beyersdorf F, Praz F, et al. 2021 ESC/EACTS guidelines for the management of valvular heart disease[J]. Eur Heart J, 2021: ehab395. doi: 10.1093/eurheartj/ehab395. Online ahead of print.

46 Chakravarty T, Søndergaard L, Friedman J, et al. Subclinical leaflet thrombosis in surgical and transcatheter bioprosthetic aortic valves: an observational study[J]. Lancet, 2017, 389(10087): 2383-2392.

47 De Backer O, Dangas GD, Jilaihawi H, et al. Reduced leaflet motion after transcatheter aortic-valve replacement[J]. N Engl J Med, 2020, 382(2): 130-139.

48 Montalescot G. Valve Thrombosis after transcatheter aortic-valve replacement: the atlantis 4d computed tomography substudy[Z]. ACC, 21 Scientific Sessions: 2021.

49 Didier R, Eltchaninoff H, Donzeau-Gouge P, et al. Five-year clinical outcome and valve durability after transcatheter aortic valve replacement in high-risk patients[J]. Circulation, 2018, 138(23): 2597-2607.

50 Pibarot P, Ternacle J, Jaber WA, et al. Structural deterioration of transcatheter versus surgical aortic valve bioprostheses in the PARTNER-2 Trial[J]. J Am Coll Cardiol, 2020, 76(16): 1830-1843.

51 Jørgensen TH, Thyregod H, Ihlemann N, et al. Eight-year outcomes for patients with aortic valve stenosis at low surgical risk randomized to transcatheter vs. surgical aortic valve replacement[J]. Eur Heart J, 2021, 42(30): 2912-2919.

52 Long YX, Liu ZZ. Incidence and predictors of structural valve deterioration after transcatheter aortic valve replacement: a systematic review and meta-analysis[J]. J Interv Cardiol, 2020, 2020: 4075792.

53 Smith CR, Leon MB, Mack MJ, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients[J]. N Engl J Med, 2011, 364(23): 2187-2198.

54 Takagi H, Umemoto T. Impact of paravalvular aortic regurgitation after transcatheter aortic valve implantation on survival[J]. Int J Cardiol, 2016, 221: 46-51.

55 Leon MB, Smith CR, Mack MJ, et al. Transcatheter or Surgical Aortic-Valve Replacement in Intermediate-Risk Patients[J]. N Engl J Med, 2016, 374(17): 1609-1620.

56 Makkar RR, Thourani VH, Mack MJ, et al. Five-year outcomes of transcatheter or surgical aortic-valve replacement[J]. N Engl J Med, 2020, 382(9): 799-809.

57 Mack MJ, Leon MB, Smith CR, et al. 5-year outcomes of transcatheter aortic valve replacement or surgical aortic valve replacement for high surgical risk patients with aortic stenosis (PARTNER 1): a randomised controlled trial[J]. Lancet, 2015, 385(9986): 2477-2484.

(2021-10-08 收稿)