

急性ST段抬高型心肌梗死急诊介入治疗的预后因素研究进展

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摘 要

急性ST段抬高型心肌梗死(Acute ST segment elevation myocardial infarction, ASTEMI)是冠状动脉病变导致心脏血供急剧减少或中断, 使相应的心肌持续性缺血并严重受损的一种心脏疾病。急诊经皮冠状动脉介入(Emergency percutaneous coronary intervention, ECPICI)治疗是目前广泛使用的ASTEMI有效治疗手段之一, 其预后因素的最新研究进展受到广泛关注。现对近年来急性ST段抬高型心肌梗死急诊介入治疗的预后因素研究进展进行综述。

关键词

急性ST段抬高型心肌梗死, 急诊介入治疗, 预后因素研究进展

Research Progress in Prognostic Factors of Emergency Interventional Therapy for Acute ST Segment Elevation Myocardial Infarction

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Abstract

Acute ST segment elevation myocardial infarction (ASTEMI) is a heart disease in which coronary

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artery disease leads to a sharp decrease or interruption of the heart's blood supply, resulting in continuous myocardial ischemia and severe damage. Emergency percutaneous coronary intervention (ECPPI) is one of the most widely used effective ASTEMI therapies, and recent advances in prognostic factors have attracted widespread attention. Recent advances in prognostic factors of emergency interventional therapy for acute ST segment elevation myocardial infarction are reviewed.

Keywords

Acute ST Segment Elevation Myocardial Infarction, Emergency Intervention Treatment, Research Progress in Prognostic Factors

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1. 引言

急性 ST 段抬高型心肌梗死是指在冠状动脉粥样硬化基础上发生冠脉血供急剧减少或中断,使相应的心肌严重而持久的急性缺血所致,其心电图主要表现为相应损伤心肌面的导联出现 ST 段明显抬高。近年来一些新技术及药物协同治疗的发展明显改善了急性 ST 段抬高型心肌梗死急诊介入治疗的预后[1]。在最近 3 年的世界数据中,一些新技术的发展和诊疗的进步使急性 ST 段抬高型心肌梗死急诊介入治疗的心衰率和死亡率从原先的 6%和 14% [2], 下降到了 3%和 5% [3]。本文从时间因素及患者因素两方面对急性 ST 段抬高型心肌梗死急诊介入治疗的预后因素研究进展进行综述。

2. 时间因素

时间因素是影响急性 ST 段抬高型心肌梗死的介入治疗预后的关键因素之一,心脏缺血时间的长短直接影响心肌损伤程度及急性 ST 段抬高型心肌梗死的死亡率。美国心脏病学协会(AHA)的心肌梗死管理指南中提出越早进行介入治疗患者的预后会越好,对急性 ST 段抬高型心肌梗死患者的介入治疗是分秒必争的 [4]。时间因素又分为首次医疗接触时间(first medical contact, FMC), 门到球囊时间(door to balloon, DTB)。

2.1. 首次医疗接触时间(FMC)

急性 ST 段抬高型心肌梗死发作多久进行介入治疗的预后较好,美国心脏病学协会(AHA)的指南建议症状发作后时间为 12~24 小时的患者进行介入治疗的预后较好(Class IIa, Level of Evidence: B) [4]。欧洲心脏病学学会(ESC)的指南建议患者 FMC 大于 12 小时,存在血流动力学不稳定或者持续性心律失常时进行介入治疗预后较好(Class I, Level of Evidence: C), FMC 为 12~48 小时的所有患者应考虑常规接受介入治疗(Class IIa, Level of Evidence: B) [5]。在韩国 20 所大学医院中住院治疗的 5826 名 ASTEMI 患者早期介入治疗(FMC 小于 12 小时)和晚期介入治疗(FMC 为 12~48 小时)的 6 个月至 3 年随访预后有差异,晚期介入治疗的患者死亡率比早期介入治疗患者的死亡率高(8.0% vs. 5.3%; $p = 0.006$) [6]。急性 ST 段抬高型心肌梗死患者的症状发作后时间 FMC 与患者介入治疗后的预后是有关系的。

2.2. 门到球囊时间(DTB)

从病人进入医疗系统到接受介入治疗打开闭塞的罪犯血管之间的时间称为门到球囊时间(DTB),该时

间被定义, 并用于判断医院心血管中心的护理质量[7]。较短的 DTB 时间能够提高急性 ST 段抬高型心肌梗死患者的远期预后[8], 日本 J-MINUET 数据库中的 1639 名患者在发病后 12 小时内行介入治疗, 患者分为四组(DTB 时间小于 45 分钟, 45~60 分钟, 61~90 分钟, 大于 90 分钟), 并对这些患者的预后情况进行了 3 年的随访, 患者死亡率分别为 10.2%、15.3%、16.2%、19.3%; log-rank $p = 0.0129$ [9]。近年来一些新技术致力于缩短 DTB。日本的一项研究认为单导管介入治疗技术(single-catheter percutaneous coronary intervention, SC-PCI)的出现缩短了患者的门到球囊时间, 从而改善了患者的预后[10]。2017 年澳大利亚的医疗急救中心通过对患者的病种进行扫码, 院内公共广播系统通告的方式来缩短门到球囊时间, 扫码组中 DTB 时间显著降低了约 22.1 分钟, 时间 67.1 ± 34.9 分钟降至 45.0 ± 22.7 分钟($p = 0.001$), 有效降低了患者死亡率(4.8% vs 9.8%, $p = 0.43$) [11]。在我国采取了急诊医护人员灵活转移至其他手术室连续进行多台急诊介入手术的方法缩短了门球时间, 减少住院时间及住院总费用[12]。我国急性 ST 段抬高型心肌梗死区域协同治疗网络及省级胸痛中心的建立有效缩短了门到球囊时间, 术后 1 年死亡率降低[13] [14]。英国国家审计数据(心肌缺血国家审计项目[MINAP])中的相关研究提出现代医疗教育(PEP)通过正确引导患者就医行为, 增加了 STEMI 患者直接进入导管手术室治疗率(52%~85%), 与进入急诊室治疗相比, 减少了患者的 DTB 时间(83 vs 37 min, $p < 0.001$), 改善了患者的预后[15]。

3. 患者因素

患者本身的年龄、性别、吸烟、糖尿病史、患者经济条件患者经济条件及新技术的应用等因素对急性 ST 段抬高型心肌梗死的介入治疗预后有影响。现对上述患者因素进行逐一分析。

3.1. 年龄

年龄是 ASTEMI 患者院内死亡率和影响急诊介入手术预后因素的重要独立因素, 魁北克急性心肌梗死研究小组对魁北克省 44 家急诊医院 3741 位 ASTEMI 患者进行年龄与介入治疗的预后研究中得出随着年龄的增长, 住院死亡率从 55 岁以下患者的 2.1%急剧上升到 85 岁以上患者的 26.3%, 随着患者年龄的增长患者接受急诊介入治疗的意愿呈下降趋势[16]。老年(患者年龄大于 75 岁) TSOP 较长, 急性 ST 段抬高型心肌梗死症状表现不明显, 胸痛较少, 合并心力衰竭及脑出血等并发症较多, 急诊介入治疗后预后较差[17]。美国心脏学会科学声明总结了急性 ST 段抬高型心肌梗死与年龄相关的表现与治疗证据, 老年患者急诊介入治疗的相对和绝对禁忌症, 数据支持 85 岁以下 ASTEMI 患者行急诊介入治疗有收益, 但取决于手术可行性, 时间因素, 休克, 并发症, 而不是只看年龄[18]。虽然老年患者和年轻患者可以从急诊介入治疗中获得相同的收益, 但是老年患者的营养不良风险高, 具有认知障碍, 文化程度低, 术后依从性差等, 导致急诊介入治疗预后不良[19]。

3.2. 性别

女性患者的急性 ST 段抬高型心肌梗死急诊介入治疗的预后比男性患者差, 术后并发症更多, 一篇对 3041 名急性心肌梗塞患者性别差异的研究中得出, 女性患者介入治疗后的功能障碍率高(20.6%:12.4%, $p = 0.001$), 出血事件发生率较高(11.0%:7.8%, $p = 0.04$) [20]。而且女性患者在急性 ST 段抬高型心肌梗死急诊介入治疗后焦虑和抑郁的患病率高于男性[21]。以往的研究表明住院的 STEMI 女性患者短期死亡率高于男性患者, 为了调查 STEMI 急诊介入术后的死亡率是否有性别差异, Edina Cenko 对 2010 年 1 月至 2016 年 1 月间在 41 家医院接受 ECPCI 治疗的 8834 名患者的数据进行统计分析得出, 2657 名女性的平均年龄为 66.1 岁, 6177 名男性的平均年龄为 59.9 岁, 女性 30 天死亡率显著高于男性(11.6%:6.0%, $p < 0.001$) [22]。女性患者的 DTB 时间和 TSOP 时间比男性患者更长, 一线治疗更为延迟, 这也导致了女性患者的

预后比男性患者差[23]。

3.3. 吸烟

吸烟是急性 ST 段抬高型心肌梗死的高危因素, 那么急性 ST 段抬高型心肌梗死急诊介入治疗术后仍保持吸烟也会对患者预后造成影响。Caroline Haig 从病理生理学角度调查了吸烟、微血管病理与急性 ST 段抬高型心肌梗死急诊介入治疗预后的关系, 他对 324 例急性 ST 段抬高型心肌梗死术后患者进行了 4 年的随访, 得出吸烟与独立预测全因死亡有关(OR: 2.20; 95% CI: 1.07~4.54), 吸烟和主要不良心血管事件如心力衰竭等有关的结论(OR: 2.79; 95% CI: 2.30~5.99) [24]。Parisa Janjan 通过控制变量, 排除了年龄, 性别, 高血压, 糖尿病, 体重指数, 血脂水平等因素的干扰, 对 1975 名患者(其中 951 名吸烟者)进行了 1 年随访, 使用 Cox 模型进行估算出吸烟与死亡率增加相关 HR (95% CI: 1.56 (1.04~2.35)) [25]。

3.4. 糖尿病史

糖尿病患者血糖控制不佳, 是急性 ST 段抬高型心肌梗死急诊介入治疗术后应激性高血糖的发生率较高原因之一, ASTEMI 入院后 24 小时内的血糖差异与 30 天全因死亡率独立相关[26]。无糖尿病病史, 入院糖化血红蛋白水平低于 6.5% 的患者中, 全因死亡率和主要不良心脑血管事件(MACCEs)的累积发生率较低, 对于接受急诊介入治疗的 STEMI 患者, 血糖控制不佳或入院时应激性高血糖的患者比其他患者预后更差[27]。一篇糖尿病对急性 ST 段抬高型心肌梗死急诊介入治疗老年患者的临床试验中提出, 与无糖尿病老年患者相比, 有糖尿病史与心血管死亡率增加有关[5.5% vs. 3.3%, hazard ratio (HR) 1.7 (0.99~2.8), $p = 0.054$] [28]。有糖尿病史的患者, 严格控制血糖, 可提高急性 ST 段抬高型心肌梗死急诊介入治疗术后的生存率。

3.5. 患者的经济条件

世界上低收入和中等收入国家(LMICs)人口占世界人口的 80%, 在地理, 文化, 识字率, 医疗财政, 医疗条件, 医疗保险普及率和医疗监管方面存在很大差异, 这对 STEMI 患者急诊介入治疗术后护理提出了挑战, 因为缺乏足够的经济条件保障患者所需的术后最低程度的护理对患者的死亡率和长期预后有影响[29]。在低收入和中等收入国家急性 ST 段抬高型心肌梗死患者的经济负担和医疗需求绝对数量在大幅增加, 但在这些国家的患者通常没有稳定的就业和病休假, 不能保证患者最基本的术后药物及休息需要[30]。

3.6. 新技术的应用

人工智能可穿戴设备的在心脏病学领域已经取得了巨大的进步, 目前可以实现对急性 ST 段抬高型心肌梗死患者实时监测、远程数据传送、智能判读结果、心脏风险评估、和预测心血管事件等功能[31]。人工智能可穿戴设备不仅缩短了患者的 FMC, 还能对急性 ST 段抬高型心肌梗死急诊介入治疗后的监测护理提供方便, 降低了患者的死亡率[32]。物联网医疗技术是通过网络通信收集和交换数据, 实现管理和分析医疗数据的技术, 通过智能手机, 人工智能可穿戴设备, 电脑及云端数据存储器等获得患者的位置及疾病发作信息智能选择最优路线安排患者就医, 行急诊介入手术治疗[33] [34]。最新的心电图贴片可以动态监测心脏病患者的动态心电图约 14 天左右, 这种小型的心电图贴片可用于长期监测急性 ST 段抬高型心肌梗死急诊介入后的心律失常, 可降低患者术后不良事件的发生率[35]。

4. 小结

近年来对急性 ST 段抬高型心肌梗死急诊介入治疗的预后因素研究是冠状动脉粥样硬化性疾病相关

研究的热门领域, 本文从时间因素及患者因素两方面对急性 ST 段抬高型心肌梗死急诊介入治疗的预后因素研究进展进行了综述, 对缩短患者的首次医疗接触时间(FMC)和门到球囊时间(DTB)十分有意义, 真正体现了时间就是生命。患者本身的年龄、性别、吸烟、糖尿病史、患者经济条件及新技术的应用等均对患者急诊介入治疗的预后不同程度影响, 我们在往后的急性 ST 段抬高型心肌梗死急诊介入治疗前应该多关注患者是否有这些影响预后的因素, 这有利于降低患者的死亡率, 不仅能有效改善患者生存质量, 减轻病患家庭的经济负担, 还可以对社会医疗的进步做出贡献。

参考文献

- [1] Ciofani, J.L., Allahwala, U.K., Scarsini, R., *et al.* (2021) No-Reflow Phenomenon in ST-Segment Elevation Myocardial Infarction: Still the Achilles' Heel of the Interventionalist. *Future Cardiology*, **17**, 383-397. <https://doi.org/10.2217/fca-2020-0077>
- [2] Szummer, K., Wallentin, L., Lindhagen, L., *et al.* (2017) Improved Outcomes in Patients with ST-Elevation Myocardial Infarction during the Last 20 Years Are Related to Implementation of Evidence-Based Treatments: Experiences from the SWEDEHEART Registry 1995-2014. *European Heart Journal*, **38**, 3056-3065. <https://doi.org/10.1093/eurheartj/ehx515>
- [3] Mehta, S.R., Wood, D.A., Storey, R.F., *et al.* (2019) Complete Revascularization with Multivessel PCI for Myocardial Infarction. *The New England Journal of Medicine*, **381**, 1411-1421. <https://doi.org/10.1056/NEJMoa1907775>
- [4] O'gara, P.T., Kushner, F.G., Ascheim, D.D., *et al.* (2013) 2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*, **127**, e362-e425.
- [5] Ibanez, B., James, S., Agewall, S., *et al.* (2018) 2017 ESC Guidelines for the Management of Acute Myocardial Infarction in Patients Presenting with ST-Segment Elevation: The Task Force for the Management of Acute Myocardial Infarction in Patients Presenting with ST-Segment Elevation of the European Society of Cardiology (ESC). *European Heart Journal*, **39**, 119-177. <https://doi.org/10.1093/eurheartj/ehx393>
- [6] Dauerman, H.L. and Ibanez, B. (2021) The Edge of Time in Acute Myocardial Infarction. *Journal of the American College of Cardiology*, **77**, 1871-1874. <https://doi.org/10.1016/j.jacc.2021.03.003>
- [7] Sutton, N.R. and Gurm, H.S. (2015) Door to Balloon Time: Is There a Point That Is Too Short? *Progress in Cardiovascular Diseases*, **58**, 230-240. <https://doi.org/10.1016/j.pcad.2015.09.002>
- [8] Suwa, S., Ogita, M., Ebina, H., *et al.* (2020) Admission during Off-Hours Does Not Affect Long-Term Clinical Outcomes of Japanese Patients with Acute Myocardial Infarction. *International Heart Journal*, **61**, 215-222. <https://doi.org/10.1536/ihj.19-434>
- [9] Nishio, R., Ogita, M., Suwa, S., *et al.* (2023) Shorter Door-to-Balloon Time, Better Long-Term Clinical Outcomes in ST-Segment Elevation Myocardial Infarction Patients: J-MINUET Substudy. *Journal of Cardiology*, **81**, 564-570. <https://doi.org/10.1016/j.jjcc.2023.01.008>
- [10] Lee, K.H., Torii, S., Oguri, M., *et al.* (2022) Reduction of Door-to-Balloon Time in Patients with ST-Elevation Myocardial Infarction by Single-Catheter Primary Percutaneous Coronary Intervention Method. *Catheterization and Cardiovascular Interventions*, **99**, 314-321. <https://doi.org/10.1002/ccd.29797>
- [11] Koh, J.Q., Tong, D.C., Sriamereswaran, R., *et al.* (2018) In-Hospital "CODE STEM" Improves Door-to-Balloon Time in Patients Undergoing Primary Percutaneous Coronary Intervention. *Emergency Medicine Australasia*, **30**, 222-227. <https://doi.org/10.1111/1742-6723.12855>
- [12] Khot, U.N., Johnson, M.L., Ramsey, C., *et al.* (2007) Emergency Department Physician Activation of the Catheterization Laboratory and Immediate Transfer to an Immediately Available Catheterization Laboratory Reduce Door-to-Balloon Time in ST-Elevation Myocardial Infarction. *Circulation*, **116**, 67-76. <https://doi.org/10.1161/CIRCULATIONAHA.106.677401>
- [13] Duan, T., Xiang, D., Qin, W., *et al.* (2014) Impact of Establishing Regional Collaborative Network on Reperfusion Time and Prognosis of Patients with ST-Segment Elevated Myocardial Infarction Admitting to Community Hospitals without Percutaneous Coronary Intervention Capacity. *Chinese Journal of Cardiology*, **42**, 641-645.
- [14] Xiang, D.C., Duan, T.B., Qin, W.Y., *et al.* (2013) Impacts of Establishment of Chest Pain Center on the Door-to-Balloon Time and the Short-Term Outcome after Primary Percutaneous Coronary Intervention of Patients with ST Segment Elevated Myocardial Infarction. *Chinese Journal of Cardiology*, **41**, 568-571.
- [15] Mahadevan, K., Sharma, D., Walker, C., *et al.* (2022) Impact of Paramedic Education on Door-to-Balloon Times and Appropriate Use of the Primary PCI Pathway in ST-Elevation Myocardial Infarction. *BMJ Open*, **12**, e046231.

- <https://doi.org/10.1136/bmjopen-2020-046231>
- [16] Boucher, J.M., Racine, N., Thanh, T.H., *et al.* (2001) Age-Related Differences in In-Hospital Mortality and the Use of Thrombolytic Therapy for Acute Myocardial Infarction. *CMAJ*, **164**, 1285-1290.
- [17] Corsini, F., Scaglione, A., Iacomino, M., *et al.* (2006) Acute Myocardial Infarction in the Elderly. A Case-Control Study with a Younger Population and Review of Literature. *Monaldi Archives for Chest Disease*, **66**, 13-19. <https://doi.org/10.4081/monaldi.2006.537>
- [18] Alexander, K.P., Newby, L.K., Armstrong, P.W., *et al.* (2007) Acute Coronary Care in the Elderly, Part II: ST-Segment-Elevation Myocardial Infarction: A Scientific Statement for Healthcare Professionals from the American Heart Association Council on Clinical Cardiology: In Collaboration with the Society of Geriatric Cardiology. *Circulation*, **115**, 2570-2589. <https://doi.org/10.1161/CIRCULATIONAHA.107.182616>
- [19] Calvo, E., Izquierdo, S., Castillo, R., *et al.* (2021) Can an Individualized Adherence Education Program Delivered by Nurses Improve Therapeutic Adherence in Elderly People with Acute Myocardial Infarction? A Randomized Controlled Study. *International Journal of Nursing Studies*, **120**, Article ID: 103975. <https://doi.org/10.1016/j.ijnurstu.2021.103975>
- [20] Nanna, M.G., Hajduk, A.M., Krumholz, H.M., *et al.* (2019) Sex-Based Differences in Presentation, Treatment, and Complications among Older Adults Hospitalized for Acute Myocardial Infarction: The SILVER-AMI Study. *Circulation: Cardiovascular Quality and Outcomes*, **12**, e005691. <https://doi.org/10.1161/CIRCOUTCOMES.119.005691>
- [21] Turen, S. and Turen, S. (2023) Gender Differences in Early Complications after STEMI and Their Associations with Anxiety and Depression. *European Review for Medical and Pharmacological Sciences*, **27**, 2936-2945.
- [22] Cenko, E., Yoon, J., Kedev, S., *et al.* (2018) Sex Differences in Outcomes after STEMI: Effect Modification by Treatment Strategy and Age. *JAMA Internal Medicine*, **178**, 632-639. <https://doi.org/10.1001/jamainternmed.2018.0514>
- [23] Babiolakis, C.S., Sharma, S., Sayed, N., *et al.* (2022) The Effect of Sex on Door-to-Balloon Time in Patients Presenting with ST-Elevation Myocardial Infarction and Referred for Primary Percutaneous Coronary Intervention: A Systematic Review. *Cardiovascular Revascularization Medicine*, **37**, 120-127. <https://doi.org/10.1016/j.carrev.2021.07.011>
- [24] Haig, C., Carrick, D., Carberry, J., *et al.* (2019) Current Smoking and Prognosis after Acute ST-Segment Elevation Myocardial Infarction: New Pathophysiological Insights. *JACC: Cardiovascular Imaging*, **12**, 993-1003. <https://doi.org/10.1016/j.jcmg.2018.05.022>
- [25] Janjani, P., Salehi, N., Asadmobini, A., *et al.* (2023) Smoker Pseudo-Paradox in ST-Segment Elevation Myocardial Infarction Patients. *Folia Medica (Plovdiv)*, **65**, 243-250. <https://doi.org/10.3897/folmed.65.e80189>
- [26] Wu, S., Yang, Y.M., Zhu, J., *et al.* (2022) Impact of Glycemic Gap on 30-Day Adverse Outcomes in Patients with Acute ST-Segment Elevation Myocardial Infarction. *Atherosclerosis*, **360**, 34-41. <https://doi.org/10.1016/j.atherosclerosis.2022.10.003>
- [27] Li, Y., Li, X., Zhang, Y., *et al.* (2020) Impact of Glycemic Control Status on Patients with ST-Segment Elevation Myocardial Infarction Undergoing Percutaneous Coronary Intervention. *BMC Cardiovascular Disorders*, **20**, Article No. 36. <https://doi.org/10.1186/s12872-020-01339-x>
- [28] De Luca, G., Verdoia, M., Savonitto, S., *et al.* (2020) Impact of Diabetes on Clinical Outcome among Elderly Patients with Acute Coronary Syndrome Treated with Percutaneous Coronary Intervention: Insights from the ELDERLY ACS 2 Trial. *Journal of Cardiovascular Medicine (Hagerstown)*, **21**, 453-459. <https://doi.org/10.2459/JCM.0000000000000978>
- [29] Chandrashekar, Y., Alexander, T., Mulasari, A., *et al.* (2020) Resource and Infrastructure-Appropriate Management of ST-Segment Elevation Myocardial Infarction in Low- and Middle-Income Countries. *Circulation*, **141**, 2004-2025. <https://doi.org/10.1161/CIRCULATIONAHA.119.041297>
- [30] Salwan, R. and Seth, A. (2021) Development of ST-Elevation Myocardial Infarction Programs in Developing Countries: Global Challenges and Solutions. *Interventional Cardiology Clinics*, **10**, 401-411. <https://doi.org/10.1016/j.iccl.2021.03.010>
- [31] Mohebi, R., Chen, C., Ibrahim, N.E., *et al.* (2022) Cardiovascular Disease Projections in the United States Based on the 2020 Census Estimates. *Journal of the American College of Cardiology*, **80**, 565-578. <https://doi.org/10.1016/j.jacc.2022.05.033>
- [32] Otto, C.M. (2019) Heartbeat: Telemedicine for Echocardiography Screening. *Heart*, **105**, 261-263. <https://doi.org/10.1136/heartjnl-2019-314705>
- [33] Bender, B.F. and Berry, J.A. (2023) Trends in Passive IoT Biomarker Monitoring and Machine Learning for Cardiovascular Disease Management in the U.S. Elderly Population. *Advances in Geriatric Medicine and Research*, **5**, e230002.
- [34] Greco, L., Percannella, G., Ritrovato, P., *et al.* (2020) Trends in IoT Based Solutions for Health Care: Moving AI to the Edge. *Pattern Recognition Letters*, **135**, 346-353. <https://doi.org/10.1016/j.patrec.2020.05.016>

- [35] Pradhan, S., Robinson, J.A., Shivapour, J.K., *et al.* (2019) Ambulatory Arrhythmia Detection with ZIO(R) XT Patch in Pediatric Patients: A Comparison of Devices. *Pediatric Cardiology*, **40**, 921-924.
<https://doi.org/10.1007/s00246-019-02089-0>