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EMJ Interventional Cardiology

Review of EuroPCR Congress 2023

Interviews

Uwe Zeymer, Emmanouil S. Brilakis, and Samin Sharma discuss the future trajectory of the field

Infographic

Exploring interventions for acute myocardial infarctions

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Welcome letter

Koutsouki

Evgenia Koutsouki
Editor

Dear Readers,

I am delighted to welcome you to the 2023 issue of *EMJ Interventional Cardiology*. Our team attended the EuroPCR event in Paris, France, in May, and we were busy attending great sessions that presented live cases, the latest research, and the most interesting innovations in the field.

In this issue, we cover the main highlights from the event, and bring you our reviews of a session on technological advances in embolic protection, heart failure, and artificial intelligence, and a second on new transcatheter approaches to tricuspid regurgitation that address unmet needs in this area. We are proud to also feature interviews with three experts who discuss their research findings, important ongoing trials in interventional cardiology, and the most important recent advances in the field.

We are excited to include several articles on key topics. One discusses unmet needs in myocardial infarction with non-obstructed coronary arteries, while another offers a perspective on better metrics for coronary interventions. An article on percutaneous treatment of coronary chronic total occlusions (CTO) discusses the potential role of invasive coronary physiology assessment and coronary CT angiography in guiding management and decision-making in CTO clinical practice, as well as new strategies to minimise stent implantation in CTO lesions.

The EMJ team and I are thankful to all our reviewers, Editorial Board, authors, and interviewees for their insightful knowledge and contributions to this issue. We look forward to next year's EuroPCR and, until then, please keep an eye out for our content throughout the year!

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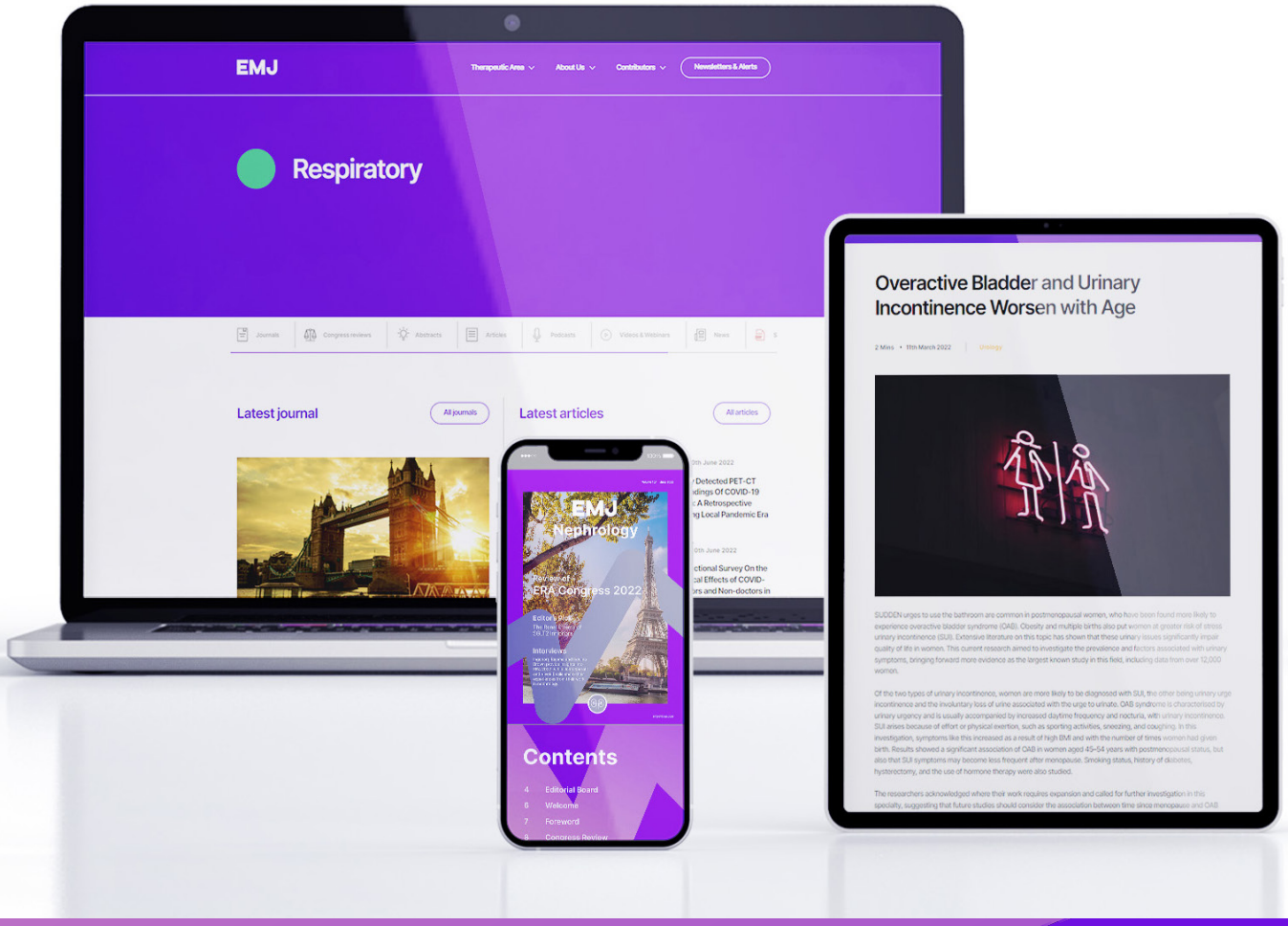

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Foreword

Dear Colleagues,

Welcome to our latest issue of *EMJ Interventional Cardiology*, featuring a range of peer-reviewed articles, interviews, and features highlighting recent advances in the field of interventional cardiology. This issue also features a review of euroPCR 2023, which took place 16th–19th May in Paris, France, providing details on the most notable content of the congress.

EMJ was delighted to speak to Emmanouil Brilakis, Center for Complex Coronary Interventions, Minneapolis Heart Institute, Minnesota, USA, who shared insights on chronic total occlusion, intravascular brachytherapy, and high risk percutaneous coronary intervention. Samin Sharma, The Zena and Michael A. Wiener Cardiovascular Institute, Icahn School of Medicine at Mount Sinai, New York City, New York, USA, spoke to EMJ about high-risk complex coronary interventions; Eternal Health Care Centre, which they co-founded; and the future of the field.

Zoumi et al.'s case report covers Vieussens' arterial ring, specifically Type Ib, a rare condition with difficulty in establishing appropriate management. The authors discuss different subtypes of the condition, investigations necessary to diagnosis, and management.

Our features explore a range of topics, with Brugaletta and Rinaldi discussing myocardial infarction with non-obstructed coronary arteries, a field that presents several unmet clinical needs. Klein covers 30-day mortality as a flawed quality indicator for coronary interventions, and Agostoni et al. present future perspectives for percutaneous treatment of coronary chronic total occlusions. Further content includes an infographic on acute myocardial infarction intervention, detailing biomarkers, interventions, a study on Tropsensor, and what's next.

I want to thank everyone who contributed to this issue of *EMJ Interventional Cardiology*, and as always, I hope you enjoy reading it and find it insightful.

Pablo Sepúlveda

Interventional Cardiologist, Division of Cardiovascular Diseases, Pontificia Universidad Católica de Chile, Santiago, Chile

EuroPCR 2023

Review of the European Association for Percutaneous Cardiovascular Interventions Congress (EuroPCR) 2023

Location:	Paris, France
Date:	16th–19th May 2023
Citation:	EMJ Int Cardiol. 2023; DOI/10.33590/emjintcardiol/10306211. https://doi.org/10.33590/emjintcardiol/10306211.

The European Association for Percutaneous Cardiovascular Interventions (EAPCI) hosted the 2023 edition of EuroPCR, a 4-day course, at the Palais des Congrès in Paris, France, attracting colleagues from around the world. This event transformed the Palais des Congrès into a vibrant hub for medical exchange and advancements in the field of interventional cardiology. The course served as a catalyst for international collaboration and innovation, creating an atmosphere of warmth and welcome to participants, as well as igniting advancement within the realm of cardiovascular medicine. Learning, collaboration, and first-hand exposure to cutting-edge innovations forging the next generation of pioneers were of great importance throughout the course.

This year's congress witnessed an unprecedented number of participants, with a record-breaking attendance of over 11,500 individuals, joining both online and in-person in Paris. The event boasted a remarkable line-up of over 900 presenters, spread across 400 educational sessions, resulting in a staggering 550 hours of programme content. Evidently, there were multiple pioneering poster, symposium, abstract, and live case sessions available for attendees to engage with.

As the opening ceremony unfolded, Jean Fajadet, Clinique Pasteur, Toulouse, France; and William Wijns, The Lambe Institute for Translational Medicine and Curam, Galway, Ireland, extended a warm invitation to the three newly appointed Course Directors, namely Thomas Cuisset, APHM Hôpital La Timone Adultes, Marseille, France; Nicolas Dumonteil, Clinique Pasteur, Toulouse, France; and Nieves Gonzalo, Hospital Clínico San Carlos, Madrid, Spain, to join them on stage.

The opening ceremony commemorated the remarkable 30-year milestone of primary percutaneous coronary intervention (pPCI) for ST-elevation myocardial infarction (STEMI), recognising the pioneers who challenged the status quo. pPCI for STEMI stands as a crowning achievement in modern medicine. Having been validated three decades ago, it serves as a prime exemplification of a life-saving cardiovascular intervention that has positively impacted millions of lives.

The directors highlighted the remarkable accomplishments of 'Stent – Save a Life', an implementation programme initiated by PCR, in driving the widespread adoption of pPCI for STEMI. They provided insights into the past when

"The opening ceremony commemorated the remarkable 30-year milestone of primary percutaneous coronary intervention."

thrombolysis was predominant a decade ago, and many doubted the feasibility of delivering pPCI for STEMI to the affected population. Numerous obstacles, including insufficient catheterisation laboratories, inadequate emergency systems, and a lack of awareness regarding patient symptoms, posed significant challenges during that time.

Colleagues from various parts of the globe were invited to provide a global perspective on pPCI. Fadajet introduced Jan Piek, Amsterdam University Medical Centers (UMC), the Netherlands, who proceeded to discuss the impact of the COVID-19 pandemic on well-established STEMI networks and the lessons learned for the future. Piek underlined the significant reduction in STEMI care, ranging from 20–50%, while out-of-hospital care experienced a seven-fold increase in some regions. Moreover, there were notable delays in hospital admissions for STEMI cases and a decrease in available intensive care unit beds, resulting in extended waiting lists and an unfortunate rise in cardiac mortality rates. The importance of adopting the best global practices, as well as developing resilient strategies to anticipate and effectively manage future pandemics was highlighted.

Emanuele Barbato, the president of EAPCI, addressed the audience regarding the historical milestones and advancements in pPCI over the past three decades. They commenced by recounting the ground-breaking achievement of Geoffrey Hartzler in 1983, who successfully performed primary angioplasty on 41 patients within 1 hour of myocardial infarction presentation. Hartzler's pioneering work led to the conclusion that "percutaneous transluminal coronary angioplasty may be performed with or without thrombolytic therapy in selected patients with acute myocardial infarction and may reduce the likelihood of late reocclusion." Barbato further highlighted the pivotal trial published in 1993, which served as the first comprehensive comparison of pPCI versus thrombolytic therapy in the USA.

Barbato highlighted the tremendous progress achieved in recent years, with pPCI now being performed within a timeframe of 120 minutes. This achievement was made possible through the establishment of round-the-clock services, the implementation of regional networks, and the adoption of efficient transfer policies, ensuring that pPCI is now accessible and performed across various locations. Hence, three decades later, pPCI has become the standard of care.

"Colleagues from various parts of the globe were invited to provide a global perspective on pPCI."

In recognition of their exceptional efforts in providing timely care to patients with STEMI, the prestigious Andreas Grüntzig Ethica award was granted to the Worldwide Emergency Services, bringing the opening ceremony to a close.

The EMJ had the pleasure of participating in this congress and is eagerly anticipating the next edition, scheduled to take place on May 14th–17th, 2024, in Paris, France. This issue of *EMJ Interventional Cardiology* includes concise summaries of the relevant press releases and abstracts presented at EuroPCR, along with informative features highlighting the latest advancements in the field of interventional cardiology. Continue reading for further insights from this year's congress.

Transcatheter Mitral Valve Replacement Versus Medical Therapy for Secondary Mitral Regurgitation

TRANSCATHETER mitral valve replacement (TMVR) is a minimally invasive treatment for heart disease and is an emerging therapy for patients with mitral regurgitation (MR). Despite several ongoing studies, TMVR has seldom been compared to guideline-directed medical therapy (GDMT). Thus, Sebastian Ludwig, University Heart & Vascular Center Hamburg, Germany, and colleagues, looked at several outcomes in patients receiving TMVR and GDMT.

The Choice MI registry and COAPT RCT databases were used to recruit 97 patient pairs, with one patient receiving TMVR and the other GDMT. Propensity score-matching ensured demographic, clinical, and echocardiographic baseline parameters, and heart failure medication were consistent across the test groups. Residual MR, New York Heart Association (NYHA) Functional Classification, all-cause mortality, and heart failure hospitalisations were investigated at 1 and 2 years post-treatment.

TMVR demonstrated a superior reduction in MR, with 100% of patients being classified as mild MR or less at both follow-up timepoints. Conversely, 7% of patients receiving GDMT were classified as mild MR or less. Similarly, TMVR demonstrated superior functional replacement when compared to patients receiving GDMT as reflected by NYHA Functional Classifications. Heart failure hospitalisations were also significantly reduced in the TMVR (32.8%) treatment group after 2 years compared to the GDMT (45.4%) group. However, no difference was seen in the rates of all-cause mortality between the GDMT (40.8%) and TMVR (36.8%) treatment groups.

Overall, TMVR using most transapical devices was associated with a significant reduction in MR, symptomatic improvement, less frequent heart-failure hospitalisations, and similar mortality in patients with secondary MR when compared to GDMT. Ludwig concluded that, in the absence of randomised controlled trials, these results provide important preliminary evidence supporting the use of TMVR.

"Despite several ongoing studies, TMVR has seldom been compared to guideline-directed medical therapy."

Effect of Residual Ischaemia After Left Main Bifurcation Stenting on Cardiovascular Mortality

AT EuroPCR 2023, Williams Wijns, The Lambe Institute for Translational Medicine and Curam, Galway, Ireland, on behalf of Bo Xu from Fuwai Hospital, Chinese Academy of Medical Sciences, Beijing, China, discussed findings from a retrospective single-centre study investigating the impact of residual ischaemia on cardiovascular mortality following stenting of the left main (LM) bifurcation.

The trial aimed to assess the rate and prognostic significance of residual ischaemia following LM bifurcation percutaneous coronary intervention (PCI). Image-based computational techniques, including the Murray law-based quantitative flow ratio (μQFR), and a new generation of angiography-based computational coronary physiology index, were utilised to evaluate the post-procedural physiology.

Residual ischaemia of physiological significance was determined by post-PCI μQFR values of ≤0.80 in the left anterior descending artery (LAD) or left circumflex artery (LCX). The assessment of post-PCI μQFR was conducted offline, and involved separate 2D-μQFR evaluations of the main vessel (left main LAD) and side branch (LCX) using different angiographic views.

The study included 1,320 patients with unprotected LM bifurcation lesions who underwent PCI with stents at Fuwai Hospital between 2014–2016. Among these patients, 71 presented with ST-elevation myocardial infarction and non-ST-elevation myocardial infarction within 72 hours. Out of the total patients, 1,249 were eligible for μQFR measurement, with 79 patients having non-analysable post-PCI μQFR. The remaining 1,170 patients underwent analysable post-PCI μQFR assessment. This patient cohort was then divided into two groups: the residual ischaemia group (N=155) and the no residual ischaemia group (N=1,015). The follow-up period of 3 years was completed by 97.4% and 98.2% of the respective groups.

The primary outcome of the study was cardiovascular death, while the secondary outcome was the bifurcation-oriented composite endpoint. The main findings revealed that post-PCI residual ischaemia was identified in 155 (13.2%) patients following LM bifurcation PCI. It was observed that patients with residual ischaemia had a notably elevated risk of cardiovascular death over a 3-year period. Additionally, a consistent and inverse relationship was observed between post-PCI μQFR and adverse events.

Based on their findings, the researchers concluded that following a successful LM bifurcation PCI, residual ischaemia assessed using μQFR was present in 13.2% of patients, and this was associated with an increased risk of cardiovascular death over a 3-year period. They emphasised the importance of incorporating a physiology-based post-PCI assessment strategy to confirm the functional success of PCI, even when the procedural outcome appears satisfactory based on anatomical criteria.

Novel Results from TRILUMINATE Pivotal Trial on Tricuspid Regurgitation Treatment Options

NOVEL data from the TRILUMINATE pivotal trial was shared at EuroPCR 2023, which took place between the 16th–19th May in Paris, France. TRILUMINATE is the first randomised controlled trial to examine the impact of tricuspid regurgitation (TR) with TriClip™ therapy. The data shared not only demonstrated the safety of the TriClip™ system but also a significant reduction in TR associated with quality of life (QoL) improvements.

The results were presented by Paul Sorajja, Valve Science Center, Minneapolis Heart Institute Foundation, Minnesota, USA; and Minneapolis Heart Institute at Abbott Northwestern Hospital, Minnesota, USA, who delved into the baseline characteristics of the patients enrolled in the trial. The average age of enrolment was 79 years, 90% had atrial fibrillation, and of the patients with previous intervention the majority had had surgical aortic or mitral valve replacements. Additionally, approximately 25% of the patients had been hospitalised for heart failure in the year prior. All the patients had significant baseline symptoms, which were causing impaired QoL.

On enrolment, the researchers also examined the morphology and function of the patients included in the study. Most of the patients (89%) had right ventricular enlargements with an average right ventricular end-diastolic diameter of 5.1 cm. An overwhelming majority of the patients had normal LV function with an average left ventricular ejection fraction of 59%. Invasive heart catheter was mandatory for all patients enrolled in the trial. Average patient's pulmonary capillary wedge pressure was 14.9, indicating well managed left sided heart disease, and those with a wedge pressure of over 20.0 were excluded from the trial. Baseline kidney and liver function were also assessed, showing that 55% of the cohort had kidney dysfunction and approximately 60% of patients had elevated gamma-glutamyl transferase, a marker of liver congestion.

The trial assessed two key endpoints: mortality at 1 year and QoL improvement without survival benefit. Mortality at 1 year was the same for device versus control for untreated LV dysfunction. However, the results for TRILUMINATE fit with similar literature on TR in untreated left sided disease with a 1-year mortality rate of 7–14%. The researchers further found that QOL improvement in TRILUMINATE was comparable or better than prior trails with established therapies.

"The trial assessed two key endpoints: mortality at 1 year and QoL improvement without survival benefit."

Outcomes From Prospective Trial on Mitral Valve Transcatheter Surgery

RESULTS from a prospective, multicentre trial evaluating 5-year outcomes for transcatheter mitral valve surgery were presented during a press conference at EuroPCR 2023, which took place between the 16th–19th May in Paris, France.

Mayra Guerrero, Department of Cardiovascular Medicine, Mayo Clinic, Rochester, Minnesota, USA, discussed the results of the MITRAL trial on behalf of the trial investigators.

The trial followed 91 high-surgical risk patients from across 13 different sites in the USA who underwent transcatheter mitral valve-in-valve (MViV; n=30), mitral valve-in-ring (MViR; n=30), or valve-in-mitral annular calcification (ViMAC; n=31) surgery, for 5 years. Survival, New York Heart Association (NYHA) classification scores, mitral valve regurgitation (MVR), mitral valve gradient, and Kansas City Cardiomyopathy quality of life scores were assessed at baseline and annually for 5 years post-surgery. At the end of the 5-year follow-up period, 22 patients remained enrolled in the MViV group, nine in the MViR group, and nine in those treated with ViMAC.

The findings showed that patients experienced a significant and sustained reduction in MVR at 5 years. The MViV group showed a higher proportion of patients displaying none/trace MVR than the MViR and ViMAC groups. However, due to the small sample size, it is difficult to draw conclusions, Guerrero stated.

Mean mitral valve gradient also reduced and remained stable at 5 years, which resulted in significant symptom improvement. Those in the MViV group displayed a higher proportion of patients in NYHA Class I and II at 5 years than those in the MViR and ViMAC groups. Quality of life scores across all three intervention groups also showed significant improvement on paired analysis at each year, compared to baseline scores.

> **"The trial followed 91 high-surgical risk patients from across 13 different sites."**

Survival was highest in patients treated with MViV (78.5% 5-year survival), compared with 34.0% and 32.0% 5-year survival rates for MViR and ViMAC treatment groups, respectively.

Guerrero concluded the results revealed that transcatheter MViV, MViR, and ViMAC using the Sapien 3 aortic transcatheter heart valve (Edwards Lifesciences LLC, California, USA) were associated with "sustained improvement of heart failure symptoms and quality of life at 5 years," and that those treated with MViV had "excellent survival at 5 years." ●

Quantitative Flow Ratio and Angiography for the Assessment of Non-Culprit Lesions

DATA comparing angiography-guided percutaneous angioplasty (PCI) of non-culprit lesions to a quantitative flow reserve (QFR)-guided strategy in patients with acute coronary syndrome (ACS) after treatment of the culprit lesions, showed no impact on prognosis and prevalence of significant angina at 12 months. The QUOMODO study was presented by Tommaso Gori, University Medical Center Mainz, Germany, at EuroPCR 2023 in Paris, France.

Approximately 50% of patients who undergo PCI for acute coronary syndrome have additional stenotic lesions in non-infarct-related coronary arteries. Current studies show that fractional flow reserve (FFR) is superior over angiography alone, as it reduces the number of lesions that need to be treated, and improves prognosis. However, FFR can be challenging in the context of ACS due to time and safety concerns. QFR, on the other hand, reflects invasive measurements well, even for non-culprit lesions, and can be measured offline.

The QUOMODO study aimed to compare angiography-guided PCI of non-culprit lesions to QFR-guided strategy in patients with multivessel disease after treatment of culprit lesions, testing whether the number of PCIs performed could be reduced and 12-month prognosis improved through offline analysis of haemodynamic relevance of non-culprit stenosis. Patients were included in the study if they were successfully treated for ACS, had at least one additional intermediate stenosis (30–75%), and were 18 years or older. In total, 200 patients were randomised 1:1 to either an angiography-guided decision, or a QFR-guided decision.

> **"QFR, on the other hand, reflects invasive measurements well."**

Results showed that use of QFR did not reduce the rate of PCI, but led to a decrease in the number of lesions referred to PCI. Furthermore, data showed no impact on patient prognosis and prevalence of significant angina at 12 months with QFR compared to angiography-guided PCI of non-culprit lesions. ●

Battle of the Values: Portico Versus Commercially Available

THERE is no significant difference in all-cause mortality risk or stoke between patients at high or extreme risk for surgery when treated with the Portico (Abbott, Santa Clara, California, USA), compared with patients treated with commercially available valves (CAV). These results were presented at EuroPCR 2023 by Raj Makkar, Cedars-Sinai Medical Center, Los Angeles, California, USA.

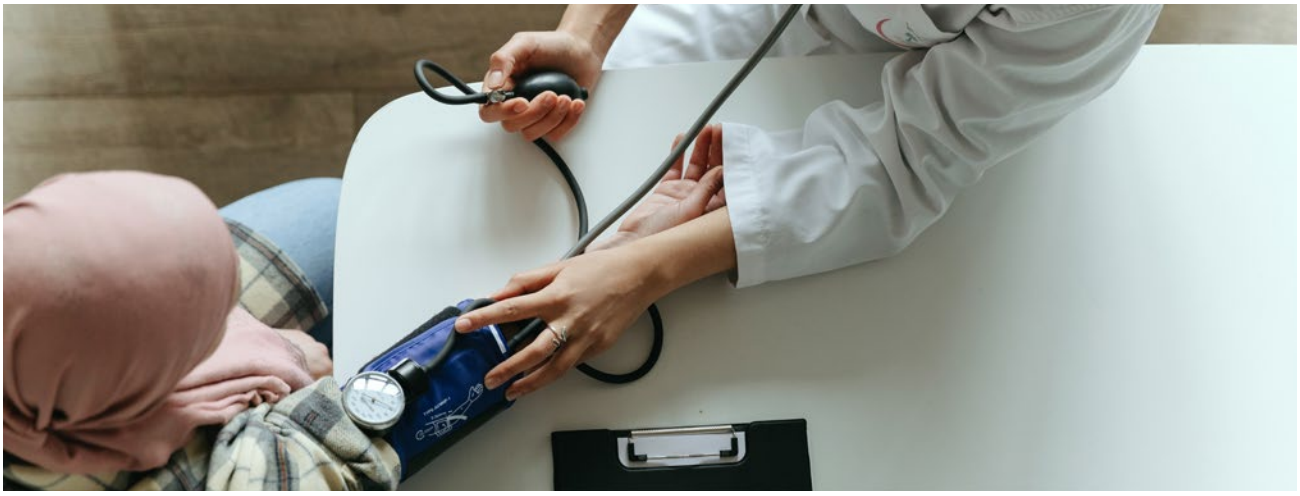
Patients from Australia and the USA enrolled into the PORTICO IDE trial between May 2014–October 2017. A total of 750 initially enrolled, with 381 being assigned the Portico valve and 369 being assigned a CAV; however, 375 were treated in the Portico group and 362 in the CAV group at the trail start. Makkar emphasised that the patients who were treated with the Portico were treated with a first-generation device, while 88% of the CAVs were contemporary.

There was no significant difference in all-cause mortality risk or stroke between the groups at the 5-year follow-up, with a rate of 55.6% in the Portico group and 51.3% in the CAV group (p=0.4154). The all-cause death rates were 52.0% in the Portico group and 48.1% in the CAV group, while the stroke rates were 11.6% and 12.9% (p=0.5612), respectively. There was also a similar reduction of symptoms and improvement in quality of life between the groups.

Furthermore, Makkar reported that there was no difference in the durability of the Portico valves and the CAVs. Both Portico valves and CAVs sustained excellent mean gradients (7.24 mmHg for the Portico group versus 9.48 mmHg in the CAV group) and in the aortic valve areas (1.78 cm^2 in the Portico group versus 1.71 cm^2 in the CAV group), with no significant difference in all-cause mortality or stroke in patients with and without reduced leaflet motion.

Finally, Makkar concluded the presentation by stating that reduced leaflet motion was not associated with clinical outcomes such as death, stroke, or valve dysfunction.

"Makkar emphasised that the patients who were treated with the Portico were treated with a first-generation device."



Renal Denervation System Effective in the Treatment of Uncontrolled Essential Hypertension

PRIMARY RESULTS presented at EuroPCR 2023 have proven both the efficacy and safety of a renal denervation (RDN) system for the treatment of uncontrolled essential hypertension.

The Netrod™ (Shanghai Golden Leaf MedTec Co. Ltd., China) system, which contains a basket-shaped design and a six-electrode catheter mounted on individual wires in a spiral array, has intelligent wall-contact detection and feedback, and is adjustable for vessels sized between 3–12 mm.

"Every patient was given a standardised drug regimen of nifedipine and hydrochlorothiazide."

The prospective, multicentre, randomised, sham-controlled clinical trial was carried out at 25 healthcare centres across China. The study included 205 patients with uncontrolled essential hypertension, all of whom were taking ≥2 anti-hypertensive drugs, and were aged between 18–65 years (mean: 50 years; 84% male).

The cohort was randomised 2:1 into an RDN group using Netrod™ (n=139, with two patients withdrawing prior to RDN procedure), and a sham control group using renal angiography (n=66). Every patient was given a standardised drug regimen of nifedipine and hydrochlorothiazide, with stable doses for ≥4 weeks. There was no statistical difference of baseline clinical characteristics between the groups, including average office blood pressure of approximately 161/100 mmHg, and average 24-hour blood pressure of 152/96 mmHg. Both groups underwent follow-up at 7 days or discharge, and then 1-, 2-, 3-, and 6-months post-procedure. Urine mass spectrometry was utilised to ensure drug adherence across the cohort.

The primary endpoint of office systolic blood pressure reduction from baseline was found to be significantly greater in the RDN group than the sham group 6 months post-procedure (25.2±13.9 versus 6.2±12.5 mmHg; $p<0.01$), with a difference between the groups of 19.0 (95% confidence interval: 15.0–23.0). The reduction in office diastolic blood pressure and mean 24-hour ambulatory systolic and diastolic blood pressure 6-months post-procedure was also significantly greater in the RDN group ($p<0.001$). Patients who were given denervation treatment were more likely to achieve the target office systolic blood pressure of 90–140 mmHg (64.7% versus 7.7%; $p<0.0001$), as well as ≥5 mmHg reduction in office systolic BP (93.4% versus 60.0%; $p<0.0001$).

Study author Gao Fei, Beijing Anzhen Hospital, China, commented: "Currently, evidence suggests that RDN technology could provide a potential therapeutic option for patients with uncontrolled hypertension," but stressed that there was "room for improvement." ●

Trans-Septal Mitral Valve Replacement: First-in-Man Primary End-Point Outcomes

FASCINATING results from the first human trial of trans-septal mitral valve replacement (TSMVR) were presented at EuroPCR 2023, which took place from 16th–19th May in Paris, France. The trial focused on the use of HighLife TSMVR in symptomatic patients with Grade ≥3 mitral incompetence and at high risk for surgical treatment.

Stephen Worthley, Macquarie University, Sydney, Australia, shared results from the single-arm, prospective, multicentre, non-randomised, open-label study during the press conference session. The study included 52 consecutive patients, with 50 of the participants receiving a valve. The primary endpoint was to evaluate the feasibility, safety, and performance of the valve at the 30-day point.

Worthley explained how one of the common issues encountered in transeptal and transcatheter mitral valve replacements is gaining valve stability once secured in the mitral annulus due to its flexibility. The HighLife TSMVR uses a unique valve and ring concept, in which the sub-annular implant is placed underneath the mitral valve to capture all of the cords. This acts as a pseudoannulus within which the hourglass stent frame can be delivered through a transeptal puncture across the mitral valve.

The patient population had an average age of 75.2 years, and 90% were patients with functional mitral regurgitation. The study group also presented with a range of comorbidities, including hypertension (67%), having had prior percutaneous coronary intervention (46%), and a prior pulse generator (42%). Clinical safety outcomes showed that a number of adverse events occurred during this trial. Seven of the participants did not survive the 30-day primary endpoint. Seven patients experienced life-threatening bleeding events, consisting of pericardial tamponade, which occurred either due to the transeptal puncture, or ring delivery. Overall, 15 adverse events were hierarchically observed, meaning 28.8% of patients at the primary endpoint of 30 days experienced a safety concern.

Worthley presented the efficacy data from the HighLife TSMVR trial, which at the 30-day endpoint had a data set of 40 patients. Of these, over 90% had a trace of or no mitral incompetence. This trend was sustained over the 3-month to 1-year follow-up analyses. Overall, this study showed an 88% technical success rate. In order to further investigate this technology, the study will expand through further patient enrolment. Worthley noted that the study was an “acceptable early experience,” and explained that the safety events observed are to be examined for key learnings that can be applied to the wider investigation.

"The primary endpoint was to evaluate the feasibility, safety, and performance of the valve at the 30-day point."

Technological Advances: Embolic Protection, Heart Failure, and Artificial Intelligence

Authors: Abigail Craig, EMJ

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IN a highly interesting session delivered at the European Association of Percutaneous Cardiovascular Interventions (EuroPCR) congress 2023, experts presented and discussed a range of exciting new technologies. Specifically, embolic protection devices, a clot aspiration pump, and a device that scores calcified aortic valves were presented, along with an intelligent conversational transcatheter aortic valve implantation (TAVI) agent. Chaim Lotan, Chief Innovation Officer, Hadassah Medical Centre, Israel, chaired the session, encouraging thought provoking discussion surrounding the application of these technologies within the field of interventional cardiology.

EMBOLIC PROTECTION

Alexandre Abizaid, Hospital do Coração, Brazil, discussed a new alternative for embolic protection during TAVI, called Emboliner® (Emboline, Santa Cruz, California, USA), an embolic protection catheter designed to protect all three cerebral vessels by capturing debris in the descending aorta. According to Abizaid, this is a self-expanding, conformable, cylindrical filter (150 µm pore size) that lines the aorta, which can treat ascending aortic diameters up to 49 mm. Balloon aortic valvuloplasty and post-dilation can be performed through the sheath, making this a highly practical system. A series of three single-arm studies, with 63 patients undergoing TAVI, has shown no deaths, no cases of acute kidney injury, and three strokes, which are still to be adjudicated. With a prospective, randomised, multicentre trial of 500 patients set to begin soon, further context will be added to the value of Emboliner.

Antonio Sorropago, University of Milan, Italy, next presented FLOWer (AorticLab, Turin, Italy), a complete embolic protection device aimed at reducing the incidence of stroke following TAVI. Once positioned in the aortic arch, 1 cm upstream of the first brachiocephalic trunk, it is unsheathed opposed to the aortic wall. FLOWer is suitable for 95% of aortic geometries due to the availability of three different sizes, and the pore diameter of 60 µm catches even the smallest emboli following TAVI. Sorropago hopes to see FLOWer in the European market by the end of 2023, following the success of clinical trials. NAUTILUS, a single arm, prospective, non-randomised clinical study enrolled 75 patients with severe native aortic valve stenosis. Results indicate that FLOWer is easy to deploy, ensuring time is not added to the procedure, but most importantly, the rate of major adverse cardiac and cerebrovascular events is promising, compared to literature data. Finally, each device has been shown to capture an average of 420 particles, demonstrating its promise in reducing the incidence of stroke following TAVI.

CLOT REMOVAL

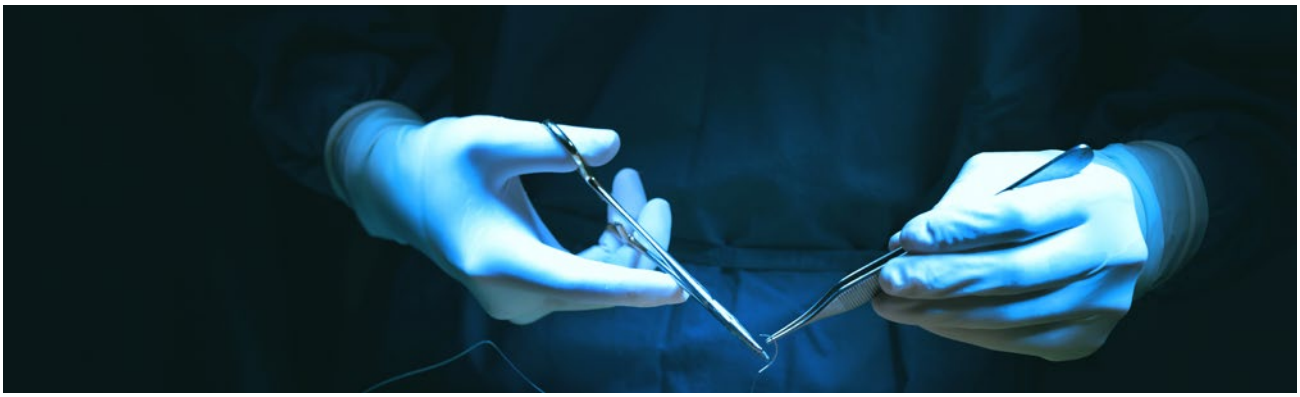
Changing gears slightly, the next presentation, delivered by Constantino Del Giudice, Institut Mutualiste Montsouris, Paris, France, outlined a pulsing aspiration pump, specifically for endovascular clot aspiration. Clot aspiration is quickly becoming a first line therapy in removing endovascular clots, providing rapid and effective

treatment that decreases hospital stay time. However, aspiration catheters may clog, requiring repeated aspiration. This results in the removal of large volumes of blood, which may decrease the patient's haemoglobin level. Subsequently, more efficient, one pass aspiration pumps are needed. Intermittent clot aspiration may allow a dynamic stretching of the clot, allowing it to adapt to the diameter of the inner catheter, reducing frictional forces and blood loss. Del Giudice introduced Quiver, a small handheld disposable pump that uses a step-up pulsing force. Demonstrating a maximum suction of 28.5 inHg, a low aspiration flow of 280 mL/min blood, and most importantly an aspirated clot volume of 110 mL, the research team are encouraged by initial testing. Thus, pulsing aspiration may improve one pass aspiration, demonstrating improved clot removal on the bench. However, further lab and clinical studies are needed to investigate the clinical value.

HEART FAILURE

Leor Perl, Rabin Medical Centre, Petah Tikva, Israel, next discussed physician-directed patient self-management of heart failure, specifically using left atrial pressure (LAP). Patients with heart failure are at an increased risk of hospital admissions, but invasive haemodynamic monitoring of pulmonary artery pressure has been shown to minimise this risk. However, remote pulmonary artery pressure sensing does not accurately estimate left-sided filling pressures in many patients with heart failure. Perl introduced a novel, battery-less, wireless, fully digital pressure monitoring system, the V-Lap™ (Vectorious Medical Technologies, Tel Aviv, Israel), which is implanted in a trans-septal fashion in the left atrium. The results of the first in-human study showed 100% successful V-Lap implantation and 97% freedom from major adverse cardiac events at 3 months. However, the initial monitoring system depended on the information being delivered to physicians who must process the data before acting on it, thus increasing the workload of healthcare professionals and isolating patients from the data. To combat this, following the implant of V-Lap, data analysis derives critical points of information, which are sent to both physicians and patients, ensuring the patients are empowered to make changes.

"Intermittent clot aspiration may allow a dynamic stretching of the clot."



Preliminary outcomes in 13 patients show they experienced persistent or very high average LAP only 10.9% of the time, and there have been no cases of heart failure related hospital admissions. Overall, results are very promising, but due to the preliminary nature of the study, results cannot be considered clinically significant.

ARTIFICIAL INTELLIGENCE

Looking to the future, Naila Loudini, University Medical Centre Groningen, the Netherlands, presented an intelligent conversational TAVI agent. TAVI is the gold-standard treatment for severe aortic stenosis; however, indications are evolving to include intermediate risk patients and possibly low risk patients in the future. This has a major impact on healthcare resource planning, especially since follow-up after TAVI is necessary but challenging. The intelligent TAVI conversational agent collects richer data from the patient, encourages therapy compliance, and is able to ask about alarming symptoms using artificial intelligence. Data are then securely transferred to the medical team. In an upcoming study comparing the intelligent agent to standard care, adherence rate is expected to be increased, with these patients expected to have better clinical outcomes. Risk factors of poor clinical outcomes and poor adherence will also be identified. Real-time patient-reported data will be invaluable in advising the treatment both of current and future patients.

AORTIC VALVE SCORING

The final session presented by Ganesh Manoharan, Royal Victoria Hospital, Folkestone, UK, discussed whether scoring the calcified aortic valve can defer the need for a permanent implant. Manoharan presented Leaflex™ (Pi-Cardia, Tel Aviv, Israel), a device designed to score the calcific part of aortic valves on the aortic side. By delivering scoring to specific areas of the three leaflets you can significantly change the patient's pressure measurement gradient from severe or moderate to mild. Following two small scale trials demonstrating that the mechanism of action increases leaflet mobility with no damage to the valve, participants are currently being enrolled in a study evaluating the safety and acute performance in patients undergoing Leaflex as a standalone treatment. Provisional results from 20 patients suggest it provides significant haemodynamic improvement with no damage to the valve and an embolic risk comparable to TAVI. The research team hope that it will replace TAVI in elderly patients and replace typical first steps in the treatment of 60–75-year-olds.

> **"The intelligent TAVI conversational agent collects richer data from the patient."**

CLOSING REMARKS

In summary, each presentation provided details of thought-provoking, exciting technological advances within the field of interventional cardiology. With several trials ongoing, each has the potential to revolutionise the clinical management of patients, streamlining the current treatment of aortic valve diseases, heart failure, aortic stenosis, and aortic valve calcification.

Novel Transcatheter Approaches to Tricuspid Regurgitation

Authors: Noémie Fouarge, EMJ

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AT the European Association of Percutaneous Cardiovascular Interventions (EuroPCR) Congress 2023 in Paris, France, a pertinent session dove into novel transcatheter approaches to valvular heart disease, including tricuspid regurgitation (TR) and aortic stenosis. Experts from different institutions across the world explored a range of novel devices to treat these conditions.

THE CROÍVALVE DUO TRICUSPID COAPTATION VALVE SYSTEM

Wojtek Wojakowski, Medical University of Silesia, Katowice, Poland, introduced the DUO Tricuspid Coaptation Valve System (CroíValve, Dublin, Republic of Ireland) as a treatment for TR. This device was designed while keeping in mind challenges faced when treating TR, including the clinical severity of patients with this condition, who often present late; the anatomic complexity, which presents a contra-indication to available therapies; and the challenge of imaging of the tricuspid valve in these patients. The DUO Coaptation valve system was created to be less dependent on imaging or anatomy, with a straightforward, quick, and well-tolerated procedure. It is composed of an anchoring system and stent, and a prosthetic valve with coaptation skirt, which is inserted through the jugular vein, under general anaesthesia, with transoesophageal echo guidelines.

The TANDEM I first-in-human trial, a prospective, non-randomised, multicentre study, aimed to demonstrate the effectiveness and safety of the system in patients with severe symptomatic TR, despite optimal medical therapy. Participants were predominantly female, with New York Heart Association (NYHA) Class III or IV, and 62.5% had massive or torrential TR. After 6 months, the trial showed a 100% reduction of TR to mild or moderate, a 100% improvement of NYHA to Class I or II, as well as a 59 point Kansas City Cardiomyopathy Questionnaire (KCCQ) increase, and a 112 m increase in 6 minute walk test. There were no major adverse events or mortality reported; however, reintervention was necessary in two cases due to sizing mismatch. Overall, Wojakowski stated the trial demonstrated the ease of use of the design, and significant improvements in symptoms in quality of life after 6 months.

> **"The DUO Coaptation valve system was created to be less dependent on imaging or anatomy."**

PIVOT-TR

Joo-Yong Hahn, Heart Vascular Stroke Institute, Samsung Medical Center, Seoul, South Korea, introduced Pivot-TR (Tau-PNU Medical Co, Yangsan, South Korea), a vertical spacer for the reduction of TR. This device is self-centring and has an atraumatic anchoring structure. The procedure is simple (<20 minutes) and there is no need for complex imaging guidance, as it is performed under fluoroscopic and transthoracic echocardiogram guidance. The device consists of two major parts: a pivot access, including distal elephant-nose and proximal spiral anchor; and an expandable 3D leaflet. It is inserted through the femoral vein using a guide wire, and the distal elephant nose is placed in the right lower pulmonary artery.

After removing the delivery catheter, the leaflet is allowed to expand and the anchor is deployed in the inferior vena cava.

Hahn then presented the Pivot balloon clinical trial, which was performed on the recommendation of the Korean FDA, and aimed to evaluate technical feasibility, early-stage safety, and preliminary efficacy of the system for patients with chronic severe to torrential TR. As the device was only left in place for less than 1 week, there are no long-term data available yet. The trial enrolled a total of seven patients, and the procedure was successful in all patients, with no procedure-related safety events reported. Echocardiographic data showed a significant decrease in vena contracta width of TR, TR jet area, and effective regurgitant orifice area; and TR decreased by two or more grades in all but one patient. Hahn explained this makes the pivot balloon a safe, feasible, and effective solution for TR reduction in humans. Next steps for this device involve an ongoing trial, which will place the device for more than 1 week, and future trials, which could explore permanent placement.

TRILLIUM™

Philipp Lurz, Leipzig Heart Center, University of Leipzig, Germany, continued the session by highlighting the "still forgotten" patient population with TR, consisting of those who are unable to get surgical treatment or currently available commercial transcatheter tricuspid valve therapies. This includes patients with lead-induced TR, those with a prior failed tricuspid repair, and those with a large coaptation gap. These populations could benefit from heterotopic therapies, such as the TRILLIUM™ (Innoventric, Ness Ziona, Israel) device, presented by Lurz. This device utilises a cross-caval anchoring and unique multi-valve design to ensure long-lasting blood flow regulation.

This self-expandable stent contains three bovine pericardial valves, and is implanted from the superior vena cava, across the right atrium, into the inferior vena cava. A sealing skirt functions to avoid backward flow. The procedure is simple and straightforward, with a device implantation time under 10 minutes, no need for echo guidance, and no need for general anaesthesia.

In total, 18 patients have benefitted from this treatment, with NYHA functional Class III or IV, reduced cardiac index, and clear reduction in kidney function. The trial resulted in 100% technical success, with an average implantation time of 6.7 minutes. After implantation, peak central venous pressure was reduced immediately, and 100% of patients experienced a reduction in TR grade to mild. Mortality was caused by multi-organ failure and sepsis in one patient, two patients suffered from acute renal failure, and one patient of phrenic nerve damage; however, according to Lurz, this reflects the already fragile patient cohort. They also noted a transient inflammatory response induced by the procedure, which resolved after a few days. Lurz concluded these data suggest that treatment with this device is safe, feasible, and efficient in

reducing backflow from the right atrium into the venous system.

TRISOL VALVE

Ran Kornowski, Rabin Medical Center, Petah-Tikva, Israel, presented the Trisol valve (Trisol Medical, Yokneam, Israel), a single dome-shaped leaflet with two commissures on both sides, anchors for ventricular fixation, as well as a ring for atrial fixation. While implantation is currently transjugular, a transfemoral approach is currently in development. Kornowski explained that the advantage of this device is that it can be used in patients with a large annulus, with the device currently supporting up to 53 mm, with 60 mm being developed.

The Trisol valve was first used in-human on 1st March 2021, at Rabin Medical Center, when compassionate use of the device was authorised for urgent use in a patient. There is now more than 2 years of follow-up for this case, showing good functional status, stated Kornowski. Since then, a pilot study with five patients has been completed to gain insights into the system's safety, and its performance in treating severe to torrential TR.

While all participants had severe to massive TR at baseline, at the latest follow-up this had decreased to none, mild, or moderate in all patients. Furthermore, NYHA had decreased from III–IV at baseline to I–II at follow-up. In the last two cases, the design was improved from six to 12 anchors to facilitate the capturing of valve leaflets. Surgical reintervention was necessary in one case due to partial valve detachment, and one patient died 69 days post-procedure due to acute renal failure and sepsis (not procedure or device related). Kornowski concluded that the results of this trial are promising, as all cases showed a reduction in TR, improvement in NYHA, and no reduction in right ventricular function.

CONCLUSION

Patients with TR often have comorbidities, require frequent hospitalisations, and have an increased risk of mortality. There remains an unmet need for less invasive treatments when it comes to this condition, due to the high surgical risks. The transcatheter approaches presented at this session offer a shorter, more straightforward procedure to treat TR, providing options for patients who are unable to receive currently available treatments.

"Kornowski explained that the advantage of this device is that it can be used in patients with a large annulus."

Abstract Reviews

Sharing key findings from the latest research in interventional cardiology from novel abstracts presented at the 2023 edition of the European Association for Percutaneous Cardiovascular Interventions (EuroPCR) Congress.

Comparative Performance of Stents in 3D-Printed Left Main Bifurcation Models

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Keywords: Bifurcation percutaneous coronary intervention, coronary intervention, 3D-printed phantom coronary models.

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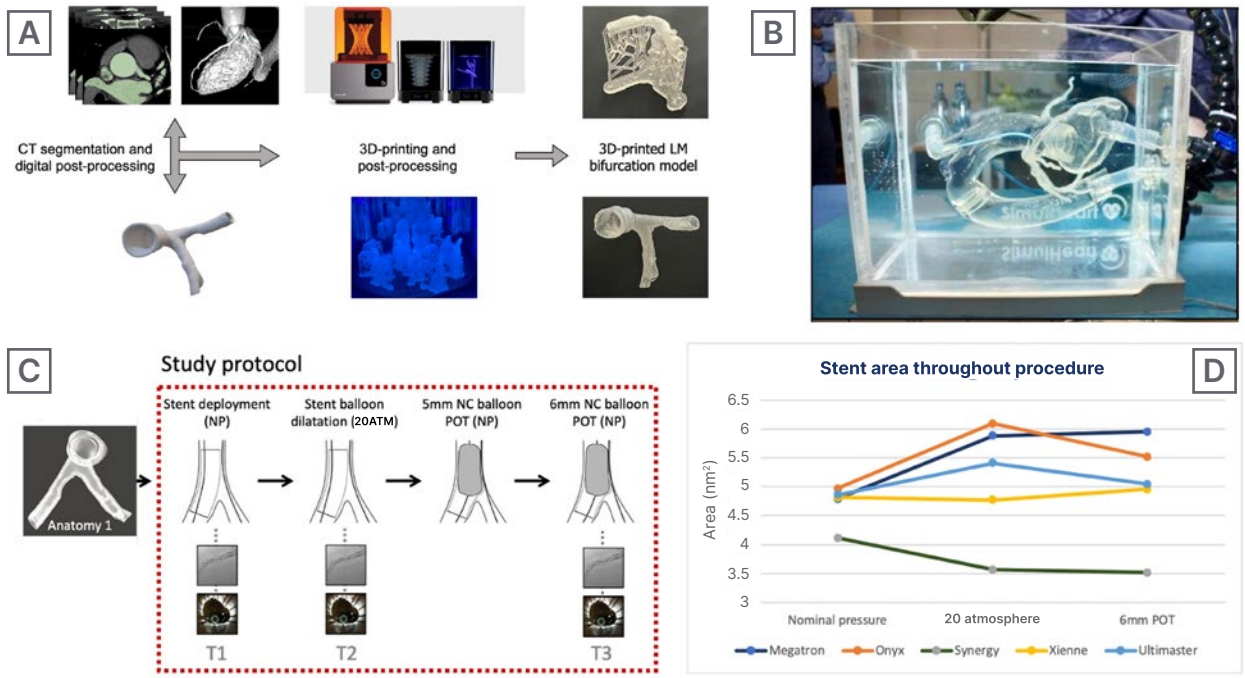
BACKGROUND AND AIMS

Percutaneous coronary intervention of bifurcation lesions accounts for approximately 20% of intervention,[1,2] and leads to higher risk of restenosis, thrombosis, and recurrent adverse clinical events.[1-4] The mismatch between the proximal and the distal landing zone constitutes the major anatomical challenge and interventions in left anterior descending artery (LAD) ostial lesions remain defiant.[3] A left main (LM) to LAD crossover stenting provides favourable outcomes, but challenges current devices.[1] There is a need for comparative, independent data on the performance of currently available stents. In clinical practice, wide anatomical variation impairs such studies. However, 3D-printing allows accurate anatomical reproduction that can be used in simulation testing.[5,6] The aim was to assess stent performance in 3D-printed diseased LM bifurcation model (Medina classification 0,1,0) using a realistic simulation environment.

MATERIALS AND METHODS

A standard realistic LM anatomy with an eccentric ostial LAD lesion was replicated using 3D-printing (Figure 1A). Tests were performed on a realistic pulsatile flow simulator in the catheterisation laboratory (Figure 1B). Five 3.5 mmx18–21 mm stents (XIENCE [Abbott, Abbott Park, Illinois, USA]; Onyx [Medtronic, Minneapolis, Minnesota, USA]; SYNERGY™ [Boston Scientific, Marlborough, Massachusetts, USA]; SYNERGY MEGATRON™ [Boston Scientific]; and Ultimaster [Terumo Corporation, Tokyo, Japan]) were implanted in 3D-printed models using a standardised protocol (Figure 1C) that included proximal optimisation technique (POT). Angiographic and optimal coherence tomography (OCT [Abbott]) runs were acquired at each procedural step, and images were blindly reviewed and analysed offline. The authors report descriptive and comparative data of stent platform performance with a focus on stent placement accuracy, longitudinal deformation, over-expansion ability, and radial strength.

Figure 1: Study workflow and protocol.



A) Workflow of simulated interventional and intravascular imaging procedure. The 3D-printed LM anatomies; **B)** the 3D-printed LM anatomies were connected to SimulHeart® (3DCardioSolutions®, Coimbra, Portugal) Interventional Cardiology Simulator; **C)** study protocol – provisional stenting; **D)** stent area throughout the procedure.

LM: left main; NP: nominal pressure; POT: proximal optimisation technique.

RESULTS

In total, five test procedures were performed, and a total of 15 OCT runs and 20 angiographic images were reviewed. Stent placement accuracy, defined as balloon marks to stent distance in angio, was highest with XIENCE (0.27 mm) and lowest with SYNERGY™ (1.01 mm). Proximal overexpansion ability after sequential 5 mm and 6 mm POT was also highest with XIENCE (stent area: 26.99 mm^2), and lowest with SYNERGY™ (stent area: 15.58 mm^2). Regarding longitudinal deformation, OCT analysis revealed shortening of Onyx (-0.1 mm), SYNERGY MEGATRON™ (-0.4 mm), and Ultimaster (-0.7 mm) stents, and elongation of SYNERGY™ (1.4 mm) and XIENCE (+3.8 mm) after POT. In angio, there was elongation of XIENCE (+3.5 mm) and shortening of all other stents (-0.9 mm to -3.5 mm). Radial strength was highest with Onyx (minimal liminal area: 4.99 mm^2) and lowest with SYNERGY™ (4.12 mm^2). Considering eccentricity, Ultimaster achieved the lowest (0.92) and Onyx the highest (0.84). High pressure balloon inflation increased minimal liminal area in all stents except SYNERGY™ and XIENCE (Figure 1D). POT negatively impacted stent performance at the LAD ostial lesion in two of the stents that showed recoil. There was no significant correlation of proximal stent expansion and stent strut thickness (r: 0.296; p=0.629).

CONCLUSION

In this study of percutaneous coronary intervention in 3D-printed realistic models of left main bifurcation coronary artery disease, the authors have shown that stent performance is not uniform among available stents. Knowledge of strengths and weaknesses of each individual stent allows a tailored approach to bifurcation stenting in order to anticipate and optimise results.

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The Effect of Side Branch Pre-dilatation on Long-Term Mortality in Patients with Coronary Bifurcation Stenting

Authors: Dobrin Vassilev,[1] *Niya Mileva,[1] Panayot Panayotov,[1] Gianluca Rigatelli,[2] Robert Gil[3]

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Keywords: Clinical outcome, coronary bifurcation, percutaneous coronary revascularisation, side branch.

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BACKGROUND

For more than 20 years, there has been considerable progress in the treatment of coronary bifurcation lesions.[1-4] The one-stent technique with proximal optimisation is fundamental in our current philosophy of coronary bifurcation intervention.[4] According to the latest European Bifurcation Club (EBC) statements, side branch pre-dilatation (SBPD) is generally not recommended.[2-4] SBPD during coronary bifurcation interventions is a technique that is generally not recommended by the latest guidelines and consensus statements. However, the data about the clinical outcomes after SBPD from dedicated studies are surprisingly few. The objective of the current study was to explore the effects of SBPD on all-cause and cardiovascular mortality at long-term follow-up.

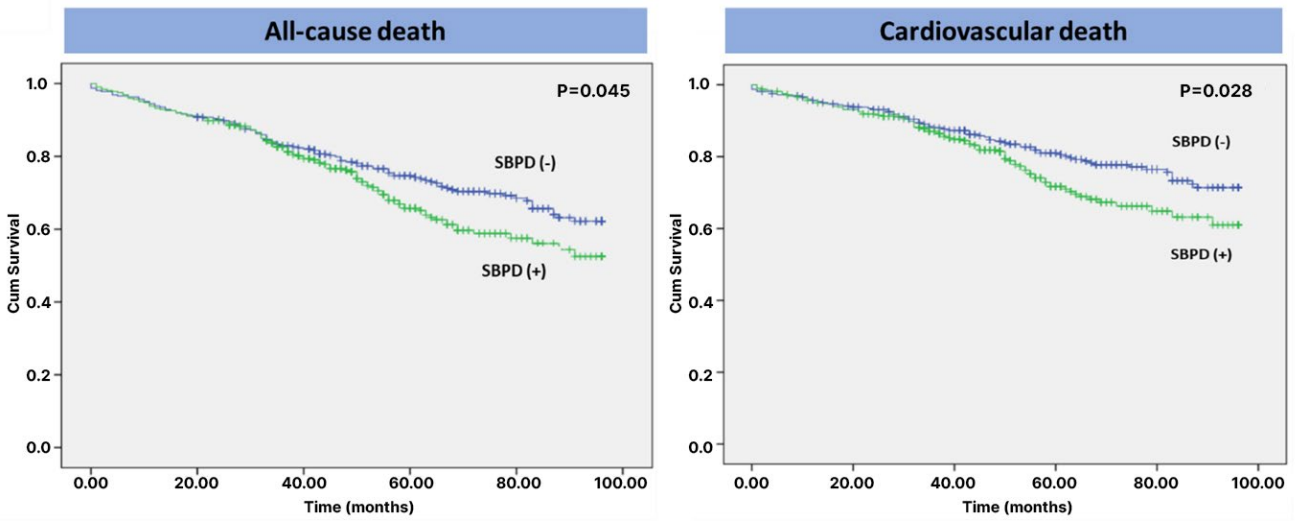
METHODS

All patients with coronary bifurcation lesions treated with percutaneous coronary intervention (PCI) between 2012–2022 were included in the prospective registry. Patients were divided into two groups, depending on performance of SBPD: SBPD performed (SBPD[+]) and SBPD not performed (SBPD[-]). For the current analysis, only patients with stable or unstable angina were included, with follow-up of at least 2 years. Patients with ST elevation myocardial infarction and left main stenosis were excluded. Propensity score matching was performed to equalise the effects of the following characteristics: age, sex, diabetes, smoking, hypertension, dyslipidaemia, renal failure, cancer, chronic obstructive pulmonary disease (COPD), atrial fibrillation, left ventricular ejection fraction, and SYNTAX score. A multivariate analysis of all-cause and cardiac mortality was performed, with SBPD as an independent variable.

RESULTS

A total of 832 patients from the registry covered the criteria for the current analysis.

Figure 1: Kaplan–Meier survival curves for all-cause mortality and cardiac mortality in groups with and without side-branch pre-dilatation.



Cum: cumulative; SBPD(-): side-branch pre-dilatation not-performed; SBPD(+): side-branch pre-dilatation performed.

After propensity score matching, 324 matched couples remained, and 648 patients were analysed. The demographic characteristics of SBPD(+) and SBPD(-) were well balanced, with no significant differences between groups. Mean age was 68±10 years, 71% were males, 40% were smokers, 47% had diabetes, 26% had a previous myocardial infarction, 53% a previous PCI, 4% coronary artery bypass surgery, 12% peripheral arterial disease, 13% COPD, 32% renal failure, 23% atrial fibrillation, and left ventricle ejection fraction was of 55±10%. Patients with SBPD(+) had more chronic total occlusions (17% versus 9%; p=0.003), longer lesions (42±21 mm versus 36±20 mm; p<0.001), and more severe side branch stenoses (68%±25% versus 41%±31%; p<0.001). Among true bifurcation stenoses (Medina xx1: 63%; 410/648), 88% were predilated. At follow-up to 100 months (median 58 [interquartile range: 37–78]), 205/648 (32%) died. Mortality among the SBPD(+) group was significantly higher (all-cause for SBP[+] versus SBP [-]: 33% [107/324] versus 30.2% [98/324], respectively; p=0.045; cardiac: 25.3% [82/324] versus 21.6% [70/324], respectively; p=0.028) (Figure 1). On Cox survival analysis, SBPD(+) was an independent predictor of all-cause mortality (odds ratio: 1.354; confidence interval: 1.003–1.828; p=0.048; with age, mitral regurgitation, left ventricle hypertrophy, pre-PCI troponin, haemoglobin, COPD) and cardiac mortality (odds ratio: 1.512; confidence interval: 1.070–2.136; p=0.019; with age, diabetes, left ventricle hypertrophy, pre-PCI troponin, COPD).

CONCLUSION

SBPD treatment of coronary bifurcation stenoses results in worse patient survival at up to 8 years following the procedure. It gives better angiographic results, but this did not translate into better clinical outcomes.

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Congress Interview

Uwe Zeymer

Interventional Cardiologist,
Klinikum Ludwigshafen, Germany

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EMJ had the pleasure of speaking to Uwe Zeymer, who shared insights into their career path, EuroPCR, and key findings from their publications.

Q1 What led you to pursue a career in interventional cardiology?

I was always fascinated by the possibility of doing some manual work, and to be able not only to do diagnostic procedures, but to perform interventions. The possibility to improve outcomes in patients with acute myocardial infarction with primary percutaneous coronary intervention (PCI) seemed especially attractive to me. Later, I was intrigued by the dramatic effect of an early invasive approach on mortality in patients with cardiogenic shock.

Q2 You currently have more than 700 international publications to your name, for example in acute cardiac care and acute coronary syndromes. What do you believe to be the current gaps in literature, and which topics merit greater attention?

The question about the prognostic impact of PCI in patients with chronic coronary syndromes deserves greater attention. Despite the fact that about half of all PCI procedures are performed in these patients, the results of randomised trial are somewhat disappointing so far. Well planned and executed trials are still needed to prove the symptomatic and prognostic impact of PCI outside acute myocardial infarction.

Q3 In the recently published observational study you authored, entitled 'Rivaroxaban in Patients with Atrial Fibrillation Who Underwent Percutaneous Coronary Intervention in Clinical Practice', what was the key message you were trying to deliver?

With this study, we prospectively collected data on a high-risk subgroup of patients: those with atrial fibrillation undergoing PCI. We were able to show that rivaroxaban in our real-world experience was as effective and safe as in the randomised clinical trial, the PIONEER-AF PCI study.[1]

Q4 You have presented several sessions at the European Association for Percutaneous Cardiovascular Interventions (EuroPCR). Can you comment on the ways in which the EuroPCR aims to serve the needs of each individual patient by helping the cardiovascular community to share knowledge, experience, and practice?

EuroPCR is a perfect platform to share knowledge in interventional cardiology, and to discuss new procedures and study results. The presentation of cases is especially educative, and helpful to improve skills and knowledge of the participants.

Q5 Over the years, you have been practising as an interventional cardiologist. What are the most significant changes you have observed in the field?

When I started my career, the only valve interventions that could be performed were balloon valvuloplasties. The advent of transfemoral aortic valve implantations has dramatically changed the spectrum of interventional cardiology, and very much improved the outcomes of elderly patients with aortic stenosis.

Q6 How have you acquired the leadership skills to perform your role as a senior cardiologist at the Klinikum Ludwigshafen in Germany?

I was trained by the late Karl-Ludwig Neuhaus, who was an innovator in the field of interventional cardiology. He taught me that randomised clinical trials are necessary to prove or disprove clinical questions in cardiology, and this is something I have tried to do over my career as a researcher.

Q7 Are there any innovations on the horizon in the field of interventional cardiology that you believe are particularly noteworthy?

As mentioned before, percutaneous valve interventions are certainly the most important advances in the field of interventional cardiology. New techniques and devices will improve outcomes and widen indications over the next years.

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Interviews

Samin Sharma and Emmanouil S. Brilakis spoke with EMJ, discussing their career paths and delving into their ground-breaking research. They shared valuable insights from impactful publications and expressed their thoughts of the field.

Featuring: Samin Sharma and Emmanouil S. Brilakis

Emmanouil S Brilakis

Director of the Center for Complex Coronary Interventions, Minneapolis Heart Institute, Minnesota, USA

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Q1 You are an investigator for the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO) trial. How might the research findings be implemented in clinical practice?

PROGRESS-CTO is a multicentre international registry of chronic total occlusion (CTO) percutaneous coronary interventions (PCI), with >12,000 procedures collected to date, and over 100 publications.

One of the most direct applications of the registry's findings to everyday practice is for evaluating the likelihood of success (using the Progress CTO score) and the risk of complications (using the PROGRESS complications scores) for each patient referred for CTO PCI. The average likelihood of success at experienced centres, such as those participating in PROGRESS-CTO, is approximately 85%, with about a 3% risk of complications. We also created an online calculator that allows an estimation of the potential success and risk of a planned CTO PCI, that can facilitate discussions with the patient and their family, and planning for the procedure.[1]

Q2 Please describe the top-line results from the Plaque Regression and Progenitor Cell Mobilization With Intensive Lipid Elimination Regimen (PREMIER) trial, and how these impact clinical practice.

The PREMIER trial randomised 160 patients with coronary syndrome without familial hyperlipidaemia after percutaneous coronary intervention to intensive lipid-lowering therapy (ILLT), comprising single LDL apheresis and statins versus standard medical therapy (SMT) with no LDL apheresis and statin therapy alone. The primary efficacy end point, percentage change in total plaque volume at 90 days by intravascular ultrasound, on average decreased by 4.81% in the ILLT group and increased by 2.31% in

the SMT group (difference of means: –7.13; 95% confidence interval: -14.59–0.34]; P=0.0611).

There was robust endothelial progenitor cell colony-forming unit mobilisation from baseline to 90 days in the ILLT group (P=0.0015), but not in SMT (P=0.0844).

Q3 Please describe your systematic, algorithmic approach for treating *de novo* and in-stent balloon undilatable lesions.

Intravascular imaging is critical for deciding how to treat balloon undilatable lesions. There are intravascular imaging criteria, using either intravascular ultrasound or optical coherence tomography, about which lesions are unlikely to respond to high-pressure balloon angioplasty with standard or plaque-modification balloons. In lesions that do not have these characteristics, high-pressure balloon inflation is performed using non-compliant or plaque modification balloons sized 1:1 with the target vessel. If high-pressure balloon inflation fails to expand the stent, as assessed by coronary angiography or intravascular imaging, intravascular lithotripsy is often done for short lesions, whereas orbital or rotational atherectomy is usually done for long lesions. Intravascular lithotripsy is preferred for in-stent lesions where orbital or rotational atherectomy is used as the last resort if all other approaches fail. The very high-pressure balloon can also be used in balloon undilatable lesions (*de novo* or in-stent), and laser with simultaneous contrast injection is sometimes performed in in-stent balloon undilatable lesions. Extraplaque lesion crossing is a complex and technically difficult procedure that can be used in either *de novo* or in-stent balloon undilatable lesions if other PCI approaches fail. If all PCI techniques fail, coronary bypass graft surgery can be considered. Our step-to-step approach to *de novo* and in-stent balloon undilatable lesions has been summarised; please see reference for further information on this algorithm.[2]

Q4 Could you discuss the evolving role of transradial access in chronic total occlusion percutaneous coronary intervention?

Radial access is increasingly used in CTO PCI with good outcomes. Two randomised trials (COLOR and FORT-CTO) showed similar technical success with lower risk of complications. There has been significant increase in the utilisation of radial access for CTO PCI in the PROGRESS-CTO registry, and currently radial/femoral are the most commonly used access site combination. Both proximal and increasingly radial access are being used for CTO PCI.

Q5 Please highlight the clinical relevance of your 2022 case report, entitled 'Complications of Stent Loss During Treatment of a Heavily Calcified and Tortuous Chronic Total Occlusion'.

The key message of this report is that trying to retrieve a lost stent can be more time consuming and more dangerous than deploying or crushing the stent. In this report, snaring the stent and forcefully trying to remove it from the coronary artery led to a perforation requiring covered stent implantation.

Q6 Could you comment on the role of intravascular brachytherapy for treating in-stent restenosis?

In the USA, where coronary drug-coated balloons are not approved for clinical use, coronary brachytherapy is currently the preferred modality for treating recurrent in-stent restenosis (two or more stent layers) as it reduces the risk of restenosis without inserting another layer of metal. Brachytherapy is by no means perfect, with approximately 30% risk of target lesion failure after 2 years, and requires indefinite dual antiplatelet therapy. Coronary brachytherapy is currently available at few centres in the USA.

Q7 Please summarise the key take-home messages for interventionists from your 2022 article entitled 'Femoral or Radial Approach in Treatment of Coronary Chronic Total Occlusion: A Randomized Clinical Trial'.

The key message of the FORT-CTO trial is that radial access can be successfully used for CTO PCI without compromising the likelihood of success, while reducing the risk of vascular access complications.

Q8 Could you provide an overview of the supportive guidewire paradox and how this can be overcome in a clinical scenario?

Using a support guidewire, such as Grand Slam (ASAHI-INTECC, Seto, Japan), or HI TORQUE IRONMAN™ (Abbott, Abbott Park, Illinois, USA), is often used to facilitate equipment delivery, especially in tortuous and calcified vessels and when guide support is suboptimal. Sometimes, however, especially in vessels that are both tortuous and calcified, use of support guidewires may lead to wire bias, paradoxically hindering equipment delivery. Switching to a less supportive guidewire may provide a solution in such cases.

Q9 Could you explain how the 'power knuckle' facilitates entry into the extraplaque space for subsequent antegrade dissection and re-entry?

Power knuckle is a technique for advancing a guidewire into the extraplaque space by placing a microcatheter proximal to the proximal cap of a CTO. A balloon usually sized 1:1 with the target vessel is inflated across the tip of the microcatheter, and a polymer-jacketed guidewire is advanced without rotation. The inflated balloon often helps to guide the wire into the extraplaque space, followed by extraplaque crossing of the CTO and re-entry distal to the distal cap.

Q10 Why might double-kissing (DK) crush be preferred over culotte when performing bifurcation stenting using an upfront two-stent strategy?

DK crush has better supporting data than culotte, including a randomised controlled trial (DKCRUSH-III) showing superiority of DK crush versus culotte. In DK crush, the wire position is always maintained in the main vessel, whereas in culotte the main vessel wire has to be removed and the vessel rewired. For both techniques, however, meticulous execution and confirmation of an optimal result is of critical importance. A well-performed culotte is superior to a poorly-performed DK crush, and vice versa. Excellent results can be achieved with either technique when performed in an expert way.

Q11 Are drug-coated balloons a feasible alternative to drug-eluting stents in patients with *de novo* small-vessel coronary artery disease?

Drug-coated balloons are very promising for treating small vessels, as long as a good result can be achieved without significant dissection and excellent antegrade flow.

Q12 In your opinion, should complex and high-risk PCI be offered to selected octogenarians and nonagenarians?

Yes! While we know that the risk of complications is significantly higher when performing PCI in octogenarians and nonagenarians, compared with younger patients, many of those elderly patients are very functional, and PCI could improve their quality and possibly quantity of life. A thorough discussion and explanation of the risks and benefits of the procedure is particularly important for this group of elderly patients.

Q13 Finally, is there anything else that you would like to add?

Learning how to perform PCI, especially complex PCI, is a lifelong endeavour.
Always striving to improve success and decrease the risk of complications is critical for achieving the best possible outcomes. With the proper training and practice, everyone can become better at performing PCI. We are currently exploring the road to mastery in the Sensei podcast, that interviews expert interventionalists from around the world.

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"Always striving to improve success and decrease the risk of complications is critical for achieving the best possible outcomes".

Samin Sharma

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Q1 You are renowned for performing over 1,600 high-risk complex coronary interventions per year, with an extremely high success rate (greater than 99%), while achieving an extremely low complication rate (less than 0.2% major complication). What underlies this outstanding record?

When I came to the USA in 1983, percutaneous coronary intervention (PCI) was emerging as a treatment option for coronary artery disease. This was a relatively rapid advancement. Andreas Grüntzig performed the first percutaneous transluminal coronary angioplasty in 1977 and by 1981–1982 this technique had already started to gain acceptance. Despite this, I knew very little about the technique before emigrating. It was only once I arrived in the USA and started learning about the field that I decided to make it my speciality. After my residency, I completed a cardiology fellowship, an extra catheterisation and then interventional fellowship, and eventually became an attending physician in 1990. When I was attending in the cath lab, my passion was to become good at opening blockages. However, I also recognised the importance of dedication and sincerity from point zero to the end. It was not enough to master interventions in the cath lab alone, I was the first one to see a patient and was also responsible for conducting follow-up care. To me, the actual procedure represents just the middle stage. I am also heavily involved in the upstream and downstream tasks.

Over time, I gradually increased the volume of procedures I performed. Data from the state of New York revealed that I performed 572 interventions in 1994, with zero mortality. In 1998, we did a live symposium of complex coronary cases. During a 2-day period, we performed 24 live cases, including six unprotected left main coronary artery interventions. As a result of this symposium, I performed between 650 cases that year, which then increased to 800 in 1999 and 1,100 in 2000. So, I did my first 1,000 cases in the academic year of 1999–2000. Now, I perform approximately 1,800 cases each year: 1,600 in the USA and 200 in India. I have emphasised the importance of dedication and following all the common steps of a process in order to achieve the best possible outcomes. Equally important but often missed is the need to keep the patient's referring physician in the loop. I will do the angiogram and then call the primary care physician while the patient is on the table. This way, the patient hears that I am involving their physician in the decision-making process, which helps build confidence and shows that I am aware of the bigger picture.

To summarise, a lot of interventional cardiologists achieve very good results. However, in the entire state of New York, no one else does more than 1,000 PCIs. I am the only one, and I set this record in 1999–2000. This success has arisen because I consider the patient journey in its entirety and maintain excellent communication with the referring physician. This approach has also allowed me to achieve a very low complication rate despite the fact I treat complex cases.

Q2 In July 2009, you launched Complex Coronary Cases (CCClivewebcast), a live monthly webcast series. How has this helped advance the training of cardiologists globally?.

After the success of the annual CCC Symposium, I felt that there was a strong need for a teaching weekly, and this was the foundation of the start of the CCC Live Webcast. We first started monthly live performance of a complex coronary case every third Tuesday, from 8–9 a.m., and was relayed to global participants, where they can ask the question via the moderator. I also give a didactic lecture for 20–30 minutes during the webcast. We then added monthly endovascular live webcast in 2013 and Structural Heart live webcast in 2016. These live webcast events have been extremely successful now, with over 25,000 participants monthly in 175 countries globally.

Q3 Under your directorship, the CCC Symposium is now in its 22nd year. Please could you discuss the educational objectives and key take home messages from the 2022 conference? Looking ahead, what will be the primary focus of the 2023 course?

Since its inception in 1998, the emphasis of the CCC Symposium has been on showing cases, from start to finish, and highlighting the struggles. We can then explore how to overcome these challenges, such as what happens when you cannot wire and need a new device. This approach also allows us to share our thought processes with the audience. I explain the rationale behind why I selected one device over another. We also teach the importance of making complex cases as simple as possible. Often, you don't need to open each small blockage (unless the patient is very young). I believe that once you have taken care of the major blockage in older patients (those aged 70–75 years), the other blockages can be taken care of by medicine. Ultimately, addressing the major blockage is what determines the prognosis and achieves the best results. This is what we have tried to show in previous symposia and it will also be the goal of the 2023 conference.

Our field is vast, with many devices and techniques. Therefore, the specific focus of the CCC Symposium is atherectomy. Of the 12 cases performed over the course of a day, eight or nine will involve the treatment of coronary bifurcation and heavily calcified lesions. So, we try to teach people how to use atherectomy properly, safely, and in such a way that they can perform cases that otherwise would have been sent for surgery. We also keep up-to-date with the latest data. For example, 15–20 years ago, atherectomy was performed using a bigger burr and an

aggressive debulking approach. However, this was associated with more complications. Now, we have learned that a little bit of plaque modification, rather than debulking, with subsequent balloon stenting is often adequate for the treatment of calcified bifurcation lesions. For this reason, the CCC Symposium emphasises the importance of changing our philosophy and adapting our techniques to keep pace with the ever-accumulating medical evidence.

Q4 Please could you explain the rationale and background of the Eternal Heart Care Centre (EHCC), which you co-founded in your native Jaipur, India? To date, what have been the greatest achievements of the hospital?

After helping the cath lab at Icahn School of Medicine at Mount Sinai, New York City, New York, USA, become one of the best and busiest centres in the state of New York, with the highest safety rating based on the American College of Cardiology (ACC) National Cardiovascular Data Registry (NCDR) report, I dreamt of replicating this in my native Jaipur. The government gave us the land in 2009 and it took roughly 5 years to build the hospital, which is a seven-storey building with a total of 252 beds (of which 106 are intensive care unit beds). The hospital became operational in 2014 and has grown significantly in the community. It was initially only a heart hospital, but now we have also added other medical and surgical branches. One of the greatest achievements of the centre is the state-of-the-art patient care, best characterised by the 100 kidney transplants and eight heart transplants performed to date. Currently, we are in the process of applying to do a combined heart and lung transplantation. In addition to offering the best possible care, we are affiliated with Mount Sinai, which means that latest devices and special medicines can be made readily available at EHCC. Our affiliation with Mount Sinai also means that we have access to an extensive network of cardiologists, internists, neurosurgeons, urologists, and other attending physicians, who will travel from the USA to the EHCC to perform operations. Finally, I am very proud of the fact that we have established the hospital as a main centre for complex electrophysiology and coronary interventions in North India.

The guiding principles of the EHCC are also very important to me. Along with my wife Manju Sharma, who actually runs the hospital, I have helped to establish a culture where you do the right thing for the right patient. Even though complications will occur, you should not do unnecessary surgery or stenting. This concept allows us to provide the best service without unduly pressuring our doctors.

Q5 The mission of the EHCC is "to redefine healthcare by improving outcomes and experience of patients through cutting edge research and personalised clinical care including innovative, preventive, diagnostic, therapeutic, and rehabilitation services." How close are you to achieving this goal, and what further efforts are necessary?

We will continue to improve our quality of care, especially in the field of transplant medicine. At the moment, we are in the process of developing a gastrointestinal team to perform liver transplantations. After starting lung and liver transplantation services, the next step is to branch out and provide healthcare to more people. Therefore, we purchased another hospital, also in Jaipur, which we call EHCC Sanganer. In addition, we are working with two other hospitals in the state of Rajasthan, India, specifically the cities of Kota and Sikar. Our final objective is to create a foundation that will allow disadvantaged people and poor communities to access health services. To achieve this, we have created the charitable Eternal Care Foundation in Jaipur, which provides funds for medical care of needy and poor underprivileged patients.

"Importantly, we need to change our approach in treating these patients accordingly with extra emphasis on guideline directed medical therapy."

Q6 This year, you were named Director of the Mount Sinai Cardiovascular Clinical Institute (CVCI). Please could you tell us about your previous contributions to Mount Sinai's complex coronary care as well as the responsibilities you will undertake in the new role?

In this new role as the director of CVCI, I will further enhance clinical care, operations, innovation, education, and clinical research. I have been performing most of these functions for last 10 plus years but will have the authoritative title.

Q7 In your opinion, what have been the top advance of interventional cardiology in 2022?

I believe that the top advance was actually a negative finding. In people with blockages in multiple arteries, heart function is decreased, and blood flow is reduced. Previously, we thought that coronary stenting in these patients if they have viable myocardium, would improve heart function, and prolong patient survival. However, the recent REVIVED-BCIS21 trial showed that PCI did not reduce all-cause mortality or heart failure hospitalisation compared with optimal medical therapy in this patient group. Based on this study, interventionists will be careful before proceeding for percutaneous coronary intervention in patients with extensive coronary artery disease and severe left ventricle dysfunction. Importantly, we need to change our approach in treating these patients accordingly with extra emphasis on guideline directed medical therapy.

Q8 What are your recommendations for the future direction of clinical research in the field?

There are two major ongoing trials I would like to mention. Firstly, the PROTECT IV study, which aims to determine whether the Impella® (Abiomed, Danvers, Massachusetts, USA) assist device is necessary when performing complex cases, namely high-risk PCI patients with reduced left ventricular function. Secondly, the ECLIPSE trial, which is evaluating orbital atherectomy versus a conventional balloon angioplasty technique for the treatment of severely calcified lesions prior to the implantation of drug-eluting stents.

In addition, there are trials exploring optimal antiplatelet therapy post PCI, with a focus on safely abbreviating the duration of antiplatelet medications. Furthermore, numerous trials with long-term follow-up such as FREEDOM, BEST, and SYNTAX trials, which have tested PCI against coronary artery bypass grafting, and this field continues to evolve.

In my opinion, there are three significant unmet needs that need to be addressed: do you need a left ventricle assist device in patients with low ejection fraction when performing complex PCIs; whether a drug-coated balloon in native small coronary arteries is better than drug-eluting stent; and can atherectomy improve long-term outcome of patients with complex calcified lesion? I hope that we will have answers to these questions in the next few years.

Q9 Currently, you are the sponsor of a clinical trial investigating rotational atherectomy combined with cutting balloon (RotaCut Trial) to optimise stent expansion in calcified lesions. Please could you briefly describe the study design and outcome measures and highlight the wider relevance?

We all well know that rotational atherectomy is an established modality for debulking calcified lesions. However, complications especially slow flow or no flow phenomena and dissection can occur in 2–4% of cases. Further, even after successful treatment, arteries can re-stenose. Therefore, this intravascular ultrasound guided RotaCut Trial is testing whether small-burr rotational atherectomy with the addition of a cutting balloon will result in increased vessel lumen, better stent expansion, and fewer cardiac problems compared to the current standard treatment of rotational atherectomy with a medium size burr followed by high pressure balloon inflation. This is an ongoing pilot study being conducted at two sites in the USA and enrolling total 60 randomised subjects. To date, we have recruited approximately 45 patients. If this yields positive results, it will be a critical step in the development of a new

interventional technique. Of course, the next stage would be a large scale randomised, multicentre trial of 700–800 patients in order to show significant clinical treatment effect (my pilot study will prove whether the mechanism itself makes sense). We hope the RotaCut Trial will provide a framework for reducing complications associated with rotational atherectomy, by using a smaller burr while achieving more optimal stent expansion, which may correlate with better long-term clinical outcomes.

Q10 Finally, is there anything extra that you would like to add?

The field of interventional cardiology will continue to evolve and progress at a very fast pace, with the introduction of new devices and techniques to improve procedural safety and more durable long-term results.

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Acute Myocardial Infarction Interventions

Citation: EMJ Int Cardiol. 2023; DOI/10.33590/emjintcardiol/10302476. https://doi.org/10.33590/emjintcardiol/10302476.

Biomarkers[1]

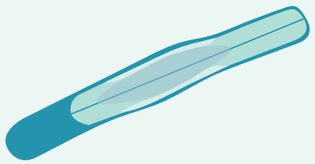
- **ECGs** are commonly employed to **diagnose** AMIs.[2,3]
  - AMI is diagnosed by:
    - The presence of pathological Q waves on the ECG.
    - New, or seemingly new, significant ST segment T wave changes, or new left bundle branch block.

BUT **only 57%** of patients can be correctly diagnosed with this technique.[4]

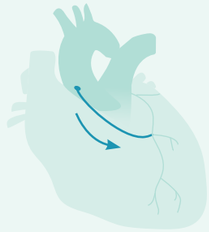
- cTn:[1]
  - **Increased cTn concentrations** are now regarded as standard biochemical markers for the diagnosis of AMI.
  - **Measuring** the amount of **cTnT** and/or **cTnI** is regarded as one of the keystones in the diagnosis of myocardial disease.

Interventions[5,6]

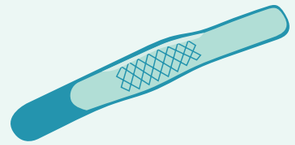
Common



Angioplasty:
a special catheter with an attached deflated balloon is threaded up to the coronary arteries.



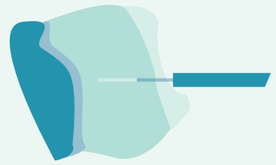
Bypass surgery:
Treats blocked arteries using veins or arterial conduits to deliver blood distal to the occluded coronary artery.



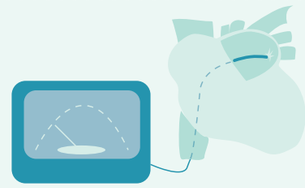
Stent procedure:
a stent is a wire mesh tube that is used to prop open an artery during angioplasty.

Uncommon

Angioplasty, laser:
similar to an angioplasty, except the catheter has a laser tip that opens the blocked artery.



Transmyocardial revascularisation:
a laser is used to drill a series of holes from the outside of the heart into the heart's pumping chamber.



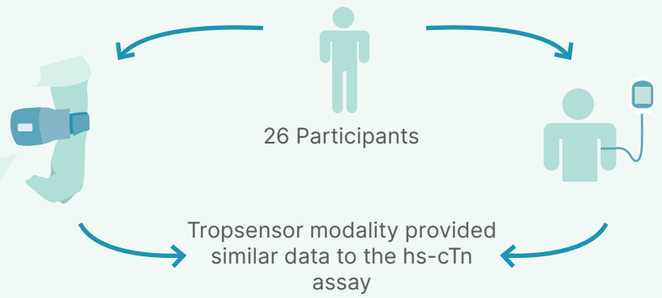
Radiofrequency ablation:
a catheter with an electrode at its tip is guided through the veins to the heart muscle to destroy carefully selected heart muscle cells in a very small area.

What Is On The Horizon?[7]

- Guidelines recommend the use of **high sensitivity** cTn (hs-cTn) for the diagnosis of acute coronary syndromes.
- Current biochemical biomarker testing relies on handling samples and blood.
  - Turnaround times are often an hour or more.
  - Difficulties include handling blood and/or samples.

- **Tropsensor** provides a non-invasive alternative method to measure hs-cTn without the need to draw blood.
  - The molecular infrared spectroscopy-based transdermal device provides a cTn readout within 5 minutes.
  - Allows for serial measurements without any of the delays or complications of blood.

Study On Tropsensor[7]



Results:

- A Pearson's correlation of **82%** with the hs-cTnI was observed.
- AMI diagnosis:
  Sensitivity = 100% **Specificity = 50%** **Accuracy = 84.6%**

Significance:

- Accelerate the assessment of patients presenting with chest pain.
- Does not require a blood draw.
- Tropsensor provides a rapid, safe, standardised, and reliable source for cTn, while allowing bedside serial trending.

Potential:

- **Streamline cardiac care workflow** by ruling out many non-cardiac patients, and identifying those with high values who are at risk.
- **Facilitate appropriate patient triage** towards early discharge of emergent treatment.

Key:
AMI: acute myocardial infarctions; cTn: cardiac troponins; cTnI: troponin I; cTnT: troponin T; hs-cTn: high sensitivity cardiac troponins.

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EMJ

Myocardial Infarction with Non-obstructed Coronary Arteries: A Yet Barely Investigated Field with Several Unmet Clinical Needs

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INTRODUCTION

Myocardial infarction with non-obstructed coronary arteries (MINOCA) is clinically defined by the evidence of myocardial infarction and macroscopical/visual appearance of normal coronary arteries at coronary angiography (any coronary artery stenosis more or equal to 50% in diameter), after excluding alternative diagnosis for troponin elevation such as Takotsubo syndrome, pulmonary embolism, sepsis, and myocarditis.[1]

MINOCA is a relevant yet commonly overlooked clinical problem for cardiologists, with a prevalence that can be as high as 10% among patients admitted for acute myocardial infarction and undergoing coronary angiography.[1,2] Compared to those with myocardial infarction due to obstructive coronary artery disease (CAD), patients with MINOCA are often younger, especially female, and less frequently have a history of traditional cardiovascular risk factors.[2]

Of note, even if it may be considered relatively benign, MINOCA has a significant impact on 12-month mortality and risk of rehospitalisation, comparable to myocardial infarction due to obstructive CAD.[3] Moreover, up to 25% of patients with MINOCA may experience recurrent angina episodes in the following 12 months.[4] Recurrent angina can have a significant impact on healthcare-related costs, leading to repeated hospitalisations and invasive procedures, as well on patients' quality of life, due to a higher probability of disability and premature retirement from the work.[5] Therefore, an appropriate management of patients with MINOCA is of mainstay importance to improve patients' prognosis, and to prevent negative socioeconomic consequences.

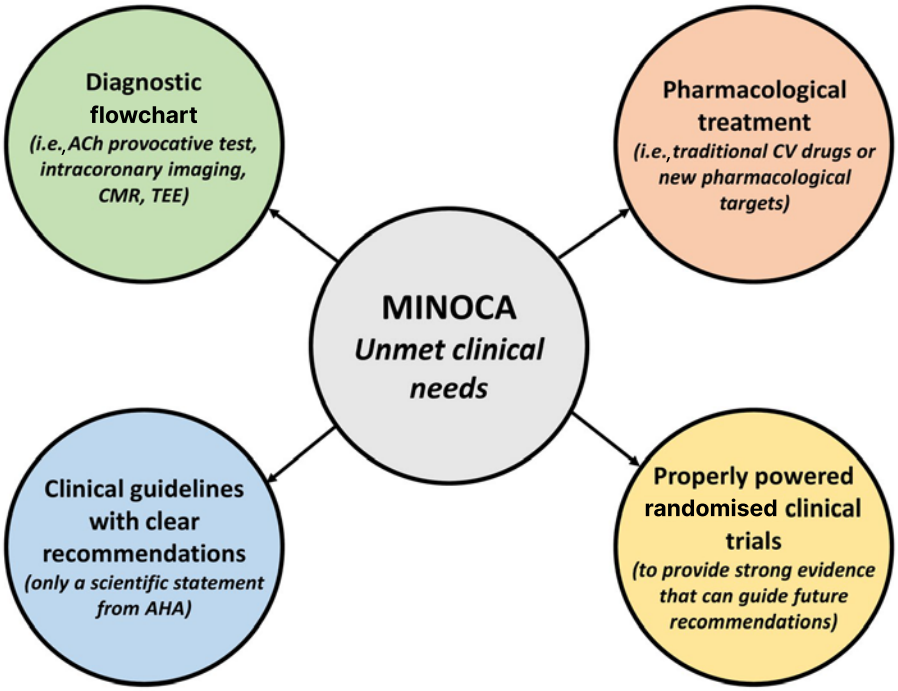
DISCUSSION

MINOCA represents an underinvestigated field of research, with some important unmet clinical needs due to the lack of an appropriate diagnostic and therapeutic consensus, and of

specific pharmacological treatment. Some clinical trials are currently ongoing to answer these questions (Figure 1).

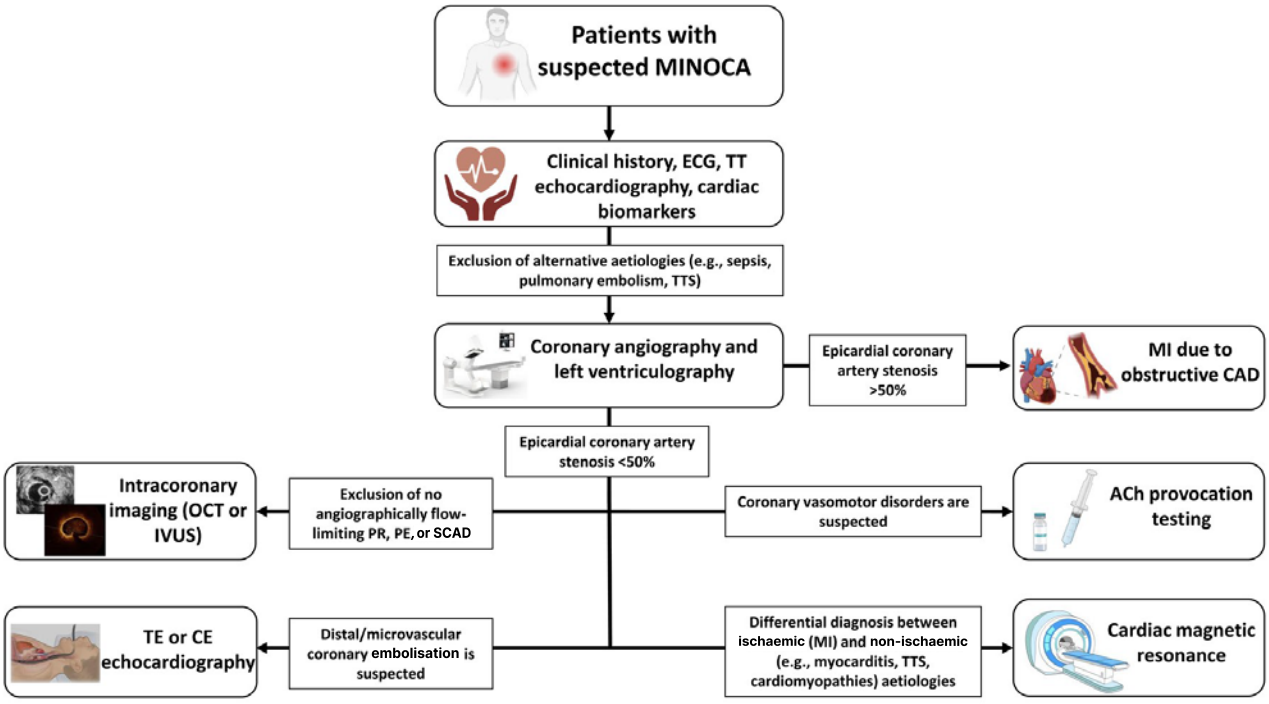
Regarding the diagnosis, there is a wide range of potential pathogenetic mechanisms underlying MINOCA, including coronary plaque rupture (PR)/plaque erosion (PE) not determining angiographically flow-limiting stenosis (due to a transient thrombosis with spontaneous thrombolysis, distal embolisation, superimposed vasospasm, or a combination of these processes), spontaneous coronary artery dissection, epicardial and microvascular vasospasm, and coronary thromboembolism leading to microvascular obstruction.[6] A pathogenetic characterisation is fundamental for the choice of the best medical approach in MINOCA: if treated uniformly as a 'unicum', each treatment does not have a uniform effect on the patient's prognosis. For example, what may be beneficial for a specific subgroup of patients (i.e., dual antiplatelet therapy [DAPT] and β-blockers improving the prognosis in patients with PR or PE), may be useless or even counterproductive in the others (i.e., DAPT leading to an unbalanced increased risk of bleeding and β-blockers favouring coronary vasoconstriction by unmasking α-adrenoreceptors in patients with epicardial coronary spasm). Therefore, the term MINOCA should not be used to refer to a specific diagnosis, but instead, to a heterogeneous 'working diagnosis' in which the application of an appropriate diagnostic workup (including invasive and non-invasive tests) can progressively help to elucidate the underlying mechanism and implement the correct therapy (Figure 2).

Figure 1: Schematic representation of the unmet clinical needs in myocardial infarction with non-obstructed coronary arteries.



ACh: acetylcholine; AHA: American Heart Association; CMR: cardiac magnetic resonance; CV: cardiovascular; MINOCA: myocardial infarction with non-obstructed coronary arteries; TEE: transoesophageal echocardiography.

Figure 2: Diagnostic flowchart in patients with suspected myocardial infarction with non-obstructed coronary arteries.



ACh: acetylcholine; CAD: coronary artery disease; CE: contrast-enhanced; ECG: electrocardiogram; IVUS: intravascular ultrasound; MI: myocardial infarction; MINOCA: myocardial infarction with non-obstructed coronary arteries; OCT: optical coherence tomography; PE: plaque erosion; PR: plaque rupture; SCAD: spontaneous coronary artery dissection; TE: transoesophageal; TT: trans-thoracic; TTS: Takotsubo syndrome.

Several advanced diagnostic techniques beyond coronary angiography and transthoracic echocardiography should be considered in MINOCA. Intracoronary provocation testing with acetylcholine is fundamental for the diagnosis of functional coronary alterations (i.e., epicardial or microvascular spasm). It has been recently demonstrated that performing an acetylcholine provocation test in patients with MINOCA is safe and has important prognostic implications, as patients with a positive response are at increased risk of future cardiovascular events compared to those with a negative one.[7] The use of intracoronary imaging, such as optical coherence tomography or intravascular ultrasound, can help to detect frequently unrecognised causes at coronary angiography (i.e., PR, PE, or spontaneous coronary artery dissection).[8,9] Cardiac magnetic resonance, thanks to its high accuracy in discriminating between ischaemic or non-ischaemic aetiologies, may help in the differential diagnosis between myocardial infarction, inflammatory cardiac diseases (e.g., acute pericarditis or myocarditis), and Takotsubo syndrome. Transoesophageal echocardiography or contrast enhanced echocardiography may be helpful if distal/microvascular coronary embolisation is suspected based on the presence of risk factors, such as atrial fibrillation, mechanical valves, or thrombophilic disorders.

It is of note that many hospitals do not have such diagnostic workup well organised in their clinical practice yet, mainly because of lack of knowledge, or because there are no clear recommendations from clinical guidelines. Therefore, there is a need for an appropriate and validated diagnostic flowchart that should be implemented in clinical practice when managing patients with MINOCA, to avoid leaving the diagnosis to cardiologists'

discretion and/or expertise.[10] To date, only the American Heart Association (AHA) has tried to summarise and unify the diagnostic alghorithm and therapy in MINOCA in a scientific statement. In this document, a 'traffic light' sequence for the diagnosis of MINOCA was proposed, but no clear indications about use of adjunctive tests to coronary angiography were given, likely because of limited evidence-based literature.[2] Conversely, the most recent European Society of Cardiology (ESC) clinical guidelines for patients presenting with acute coronary syndromes do not specifically address and delineate appropriate management of MINOCA.[11,12] Management of MINOCA should be properly addressed in the upcoming clinical guidelines or in appropriate scientific consensus documents, especially by the European societies, given the lack of European documents.

Furthermore, although identification of the underlying MINOCA aetiology may guide a proper and customised acute and long-term treatment, there are few data about what is the best pharmacological treatment. In a large study including 9,136 patients with MINOCA enrolled in the SWEDEHEART registry, the use of statins and renin-angiotensin system inhibitors led to a significant reduction in the rate of major adverse cardiovascular events (defined as all-cause mortality, hospitalisation for myocardial infarction, ischaemic stroke, and heart failure) at a mean follow-up of 4.1 years. A trend for a reduction of events was observed with the use of β-blockers, while DAPT, the cornerstone therapy for atherosclerotic obstructive CAD, had a neutral effect on clinical outcomes. However, the study cohort was extremely heterogeneous, as the specific pathogenetic mechanism leading to MINOCA was not identified and medical therapy was not modulated accordingly.[13] Moreover, available studies mainly focused on evaluating the role of traditional CV drugs (i.e., angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, β-blockers, statins, and DAPT) in MINOCA, with only few ongoing RCTs investigating the best approach and pharmacological management. MINOCA-BAT is an ongoing clinical trial that aims to evaluate if a therapy with oral β-blockers or angiotensin-converting enzyme inhibitors/angiotensin receptor blockers may reduce the incidence of all-cause death, readmission because of myocardial infarction, ischaemic stroke, or heart failure in patients discharged after MINOCA with left ventricular ejection fraction ≥40%.[14,15]

StratMed-MINOCA[16] is an ongoing clinical trial that will determine whether an early risk stratification by coronary microvascular dysfunction (defined by an index of microvascular resistance ≥25) associated with cardio-protective mineralocorticoid antagonist therapy with eplerenone could reduce the changes of levels of N-terminal pro-brain natriuretic peptide as marker of myocardial damage in patients with MINOCA. The ongoing PROMISE[17] clinical trial will evaluate whether a 'precision medicine approach', defined as a comprehensive diagnostic workup associated with a consequent tailored pharmacological treatment for the underlying aetiology, compared to 'standard of care', consisting of coronary angiography alone and the standard treatment of myocardial infarction (DAPT in all patients, β-blockers, statins, and angiotensin-converting enzyme inhibitors/angiotensin receptor blockers if clinically indicated), may improve patients with MINOCA's prognosis and quality-of-life.[18]

Further studies are strongly warranted either to gain a deeper insight into the pathophysiology of MINOCA, or to explore new potential pharmacological targets in MINOCA such as circulating biomarkers (e.g., endothelin-1 and neuropeptide Y) involved in coronary vasomotion,[19] platelet-derived soluble CD40-ligand and myeloperoxidase involved in plaque destabilisation,[20] and small circulating non-coding RNA (e.g., microRNA involved in many cellular pathways, such as proliferation, angiogenesis, differentiation, and apoptosis).[21]

CONCLUSION

In conclusion, although the prevalence of MINOCA is likely to increase in the next years, the diagnostic and therapeutic approach of patients with MINOCA is still unclear and frequently left at cardiologists' discretion, or based on the experience of each centre. Therefore, MINOCA represents an urgent unmet clinical need that should be properly addressed in future clinical guidelines or expert consensus documents.

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30-Day Mortality Is a Flawed Quality Indicator for Coronary Interventions: Why Interventionalists Should Insist on Better Metrics

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The accurate appraisal of operator and programmatic quality of percutaneous coronary interventions (PCI) is a fundamental principle of interventional practice. Identifying areas of potential improvement is vital to delivering optimal outcomes. Moreover, patients have the right to know the competency of the operators and programmes available to them in order to make better-informed consumer choices.[1-3] Therefore, every interventionalist should be familiar with how PCI quality is measured and how the metrics are analysed.

Public reporting programmes routinely emphasise unadjusted 30-day survival as the standard metric of quality.[3,4] This outcome has been chosen because it is easy to obtain and is a simple measure for laypeople to grasp. Culpability is allocated if a procedure was performed within 30 days prior to a death, regardless of its contribution to the result and despite limited control over the variables predictive of outcomes. For example, the operator and the programme can not alter the size of an acute infarct, the presence of shock, the delay in arrival to the emergency department after the myocardial infarction onset, the severity and extent of coronary stenoses, or the pre-morbid conditions of the patients; factors that critically determine procedural-related mortality.

Data from registries and clinical trials demonstrate that the occurrence of PCI complications is much more dependent on patient-specific factors than on procedural error. Furthermore, the selection of very low-risk patients, together with subconscious and/or intentional risk aversion, makes performance measures such as survival subject to gaming. In clinical circumstances where very high-risk procedures are indicated, performing such cases in large volumes will often lead to false censure of excellent operators, who are willing take on the toughest cases; however, most deaths within 30 days relate to the underlying illness and not the conduct of the PCI procedure. The event rate is inherently higher in this group, and no matter how competent the team, deaths are inevitable. Consequently, 30-day mortality does not accurately reflect the cognitive or technical skills of the interventionist.

To partially correct for the confounding effects of elevated intrinsic risk of emergency and

high-risk PCI, risk adjustment algorithms have been developed that calculate an expected mortality based on a weighted formula of comorbidities associated with worse outcomes.[4,5] The 30-day risk-adjusted mortality rate (RAMR) is essentially the ratio of observed mortality to expected mortality (O:E ratio) multiplied by the average 30-day mortality rate (approximately 1.3%). However, RAMR is an insufficient metric in isolation as the adjustment algorithms fail to completely compensate for the higher risk; deaths occurring even in patients with features that make survival unlikely leave a small O:E fraction, because observed mortality (the numerator) can never be zero once there is a death. This inaccuracy accumulates with each additional death, and the more high-risk cases that are performed, even if accomplished with better-than-expected mortality results, the more inaccurate the O:E ratio becomes as a quality indicator.[6]

Recognition of this problem has led many to advocate another approach: to exclude cases from analysis that are anticipated to have a high intrinsic risk, such as acute myocardial infarction. There are statistical arguments against this proposed method, including that risk is a continuous variable, and there is no clear cut boundary to objectively 'draw the line'; any reporting that involves exclusion of deaths gives the appearance of a lack of transparency; and if deaths from high-risk cases are not counted, the mortality rate of PCI with contemporary pharmacotherapy and techniques is very low, regardless of an interventionalist's technical and cognitive abilities. Hence, finding meaningful differences to identify opportunities for improvement will be mathematically impossible. Accordingly, a single death in these cases might expose a systematic quality issue, but may also reflect high-risk not completely accounted in the algorithm. When usual risk patients die, it is typically indirectly related to bleeding, heart failure, arrhythmias, or renal failure. The occurrence of these procedural complications is most often related to pre-procedural clinical status rather than operator competence.

The absence of resolution to this complex statistical and clinical dispute has resulted in the public, who are the presumed audience for this information, not knowing how to correctly interpret the data.

Further, the apparent simplicity of the presented numbers conceals the fallacy that unversed individuals (including medical staff, quality review committees, hospital administrators, and third-party payers, who are highly interested in this information) may think that every death ought to be preventable; that is, that the ideal mortality rate is zero. But this credulous view leads to risk avoidance, both conscious and unintentional, not better quality.[7] Thus, some very high-quality physicians and laboratories that have a high-risk case mix are incorrectly identified as being of subpar quality because their O:E ratio can never be zero. Further, a consumer is unable to distinguish quality among operators with non-zero O:E ratios, without knowing the risk of the patients treated: observed mortality is routinely shared, but expected mortality is often not.

Recently, the New York State Registry decided to try a hybrid approach.[8] They will be reporting their individual RAMR but excluding acute myocardial infarction cases; however, they will report the overall programme RAMR, including all deaths to the hospital administration. The idea is to reflect individual physician routine outcomes, which are usually reported to the public, and assuage the sensitivities of the operator, while not discarding any data reflective of the programme. Most believe this is a step in the right direction, and give this registry substantial credit for exploring a new methodology, which other national and regional registries have eschewed for years. However, it is possible that this compromise in reporting could create misunderstandings between the hospital administration and catheterisation laboratory leadership, who will be working with different numbers. Moreover, this is not an authentic solution to the various methodological concerns, and may even create a new problem. When confronted with the new reports, insurance carriers or hospital administrations might insist on more conservative case selection to improve the reported outcomes, which is not what is best for patients, who despite being the highest risk patients, are the ones most likely to benefit from such procedures.

To develop a better approach, interventional cardiologists must strongly advocate ending quality assessment based primarily on procedural mortality, and instead encourage registries and in-hospital quality programmes

to incorporate metrics that genuinely reflect the excellence of care delivered. To accurately evaluate programme quality, they must identify, collect, and quantify measurable and potentially modifiable metrics that are actionable and truly representative of quality of service. An effective ongoing evaluation process relevant to contemporary practice, with appropriate benchmarks for comparison, must be adopted.

Recently, a comprehensive framework that more accurately appraises PCI quality was proposed.[9,10] Four broad aspects of practice form the basis of appraisal: case selection, technical expertise, case complexity, and clinical results. Measurable parameters in all these quality categories were identified. Quality of life, persistence of angina, re-hospitalisation, repeat revascularisation, and follow-up myocardial infarction are all critical endpoints that are currently go unreported as primary quality indicators. These outcomes should be essential components in a revised quality framework.

Additionally, reduction of specific non-fatal complications (e.g., haematomas, bleeding, new dialysis, stroke, periprocedural myocardial infarction, and stent thrombosis) should be part of the evaluation process. Case selection based on the correlation of coronary stenoses with regional ischaemia, function, and viability should be included in the assessment. The use of physiologic testing and intracoronary imaging are necessary to fully optimise strategy and results. It is extremely important that, in scenarios where the relative merits of PCI versus medical therapy or bypass surgery are debatable, substantial latitude for patient preference must be integrated.

Current guidelines that emphasise survival as the sole important outcome metric should be modified; improved mortality might be an anticipated benefit in some clinical situations, but not all. Random case review and comparison of outcomes to a disease-specific registry are also strongly suggested.

The central measure of a high-performance healthcare system is the delivery of high-value care. Value is a parameter that combines the attributes of high effectiveness and low cost. Comparing the outcomes of those treated in one programme versus similar patients treated in comparable institutions provides benchmarks of efficacy, and provides insight into risk aversity. Cost is a dominant covariate of length of hospital stay and secondary services, and hence a powerful and objective correlate of complications. If the risks, and especially the benefits compared to medical therapy seem to be equivalent, the less invasive option will be preferred. For this reason, to establish the value of our work, its effectiveness and cost benefits must be fully depicted.

Once these proper measures of excellence are accepted, the profession should embrace a more complete and balanced account of the merits of PCI, which better demonstrate the skills and proficiency of its practitioners. The time has come for interventional cardiologists to insist that such programmes be implemented, as they are essential to a full comprehension of the role of PCI in the modern treatment armamentarium. Allowing our results to be judged by inaccurate measures because they are simple and cheap to collect will continue to be detrimental to progress.

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Viewpoint on Future Perspectives for the Percutaneous Treatment of Coronary Chronic Total Occlusions

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INTRODUCTION

Percutaneous treatment of coronary chronic total occlusions (CTO) has considerably advanced over the last decades, thanks to the development of dedicated technologies and improved skills of experienced operators. Although randomised evidence on hard endpoints is lacking, the key role of CTO recanalisation in relieving symptoms and improving quality of life has been widely demonstrated. Besides, there is still a need for optimising risk assessment and patient selection, and implementing tailored treatment strategies according to lesions and patients' characteristics. Accordingly, the authors discuss the potential role of invasive coronary physiology assessment and coronary CT angiography in guiding management and decision-making in CTO clinical practice, as well as new strategies to minimise stent implantation in CTO lesions.

Percutaneous coronary intervention (PCI) of CTO is one of the most heatedly debated topics in interventional cardiology. Indeed, CTO–PCI raises unique procedural challenges and questions about the best strategy. Considering the recent development in invasive coronary physiology assessment and coronary CT angiography (CCTA) planning for structural interventions, the authors believe these relatively new tools may have their role in guiding management and decision-making in CTO clinical practice. Moreover, given the well-known higher risk of target vessel failure and need for revascularisation in CTO–PCI compared with non-CTO–PCI (partly due to more extensive stenting in CTO–PCI), the authors believe that new solutions are needed to minimise stent implantation in this procedure. The authors deem those as some of the most attractive questions about the future directions for CTO–PCI and, accordingly, they provide their opinion on the topic.

Despite the evolution in technology and techniques, CTO prevalence has remained stable, at around 20% of patients undergoing coronary angiography.[1] Moreover, in the presence of an ageing population, and the increased survival of patients with complex coronary artery disease, it is anticipated that a growing proportion of patients will present with CTO lesions. Although the success rate of CTO revascularisation has increased in the last decade (more than 90% in experienced operators' hands),[2] accompanied by a substantial reduction in complication occurrence (less than 3% of cases),[3] the indication itself to CTO–PCI remains a matter of debate. According to current literature, CTO–PCI leads to consistent symptomatic relief and quality of life improvement;[2] however, the available trials to date were not adequately powered and designed to assess the impact of CTO–PCI on hard endpoints, such as death and myocardial infarction.[4-8] Therefore, patient symptoms are currently the main drive for CTO recanalisation, along with signs of inducible ischaemia and myocardial viability in the territory of the CTO,[9] that should be confirmed especially in patients with reduced left ventricular ejection fraction.[10]

Besides, the authors believe that the optimisation of risk assessment and patient selection might further improve the expected clinical benefit, and inform on futility of interventions, thus posing a special need for tailored treatment strategies according to lesions and patients' characteristics (Figure 1).

Figure 1: Future perspectives for chronic total occlusion–percutaneous coronary intervention.

Future perspectives for CTO–PCI entail further advancing technologies, evolving expertise of dedicated operators, broadening the adoption of multidimensional and multidisciplinary assessment with integration of physiology, and anatomical characterisation, towards a refinement in patient and lesion selection and development of tailored approaches.

CTO: chronic total occlusion; PCI: percutaneous coronary intervention.

IS THERE ROOM FOR PHYSIOLOGY ASSESSMENT IN CHRONIC TOTAL OCCLUSION?

Based on the limited available studies on invasive physiology assessment in CTO lesions by means of hyperaemic or non-hyperaemic indexes (i.e., fractional flow reserve [FFR] and instantaneous wave-free flow reserve, respectively), significant ischaemia has been observed, regardless of well-developed and well-functioning collateral vessels supplying the vital CTO territories[11-13] and regional wall motion abnormalities.[14] Overall, the ischaemic burden reduced after successful CTO–PCI and improves over time.[13,15] Recent evidence has demonstrated a significant correlation between the magnitude of change in post-PCI FFR and angina relief,[16] as well as the association between larger gain in FFR with PCI and improved clinical outcomes.[17] Specific data on CTO–PCI, albeit scant, have confirmed that suboptimal post-procedural FFR predicts long-term major adverse cardiovascular events.[13] Of note, untreated focal or diffuse epicardial disease besides the CTO segment; suboptimal stenting (derived from malapposition, under-expansion, significant dissection, or plaque protrusion); microvascular dysfunction; and the complex interplay between the distal segment, coronary collaterals, and their donor vessel represent all potential pitfalls to be taken into account.

With regard to the microvascular compartment, the available studies showed inconstant improvement in microvascular function immediately after CTO recanalisation and during follow-up.[18,19] Thanks to the recent introduction of reproducible and easy-to-use tool, allowing to accurately quantify the absolute coronary blood flow and microvascular resistance, new findings on distal coronary artery physiology and microvasculature in recanalised CTO vessels are becoming available.[20,21] Future research will hopefully expand the knowledge about physiology in CTO, and shed light on the contributing factors to epicardial and microvascular dysfunction and their impact on clinical outcome in this specific setting, thus identifying those CTOs likely or unlikely to benefit from recanalisation, as well as features to guide CTO–PCI procedural and clinical optimisation. In this regard, the ongoing IMPACT-CTO 2 trial[22] will provide a substantial contribution.

CORONARY CT ANGIOGRAPHY-GUIDED CHRONIC TOTAL OCCLUSION–PERCUTANEOUS CORONARY INTERVENTION: HOW FAR ARE WE?

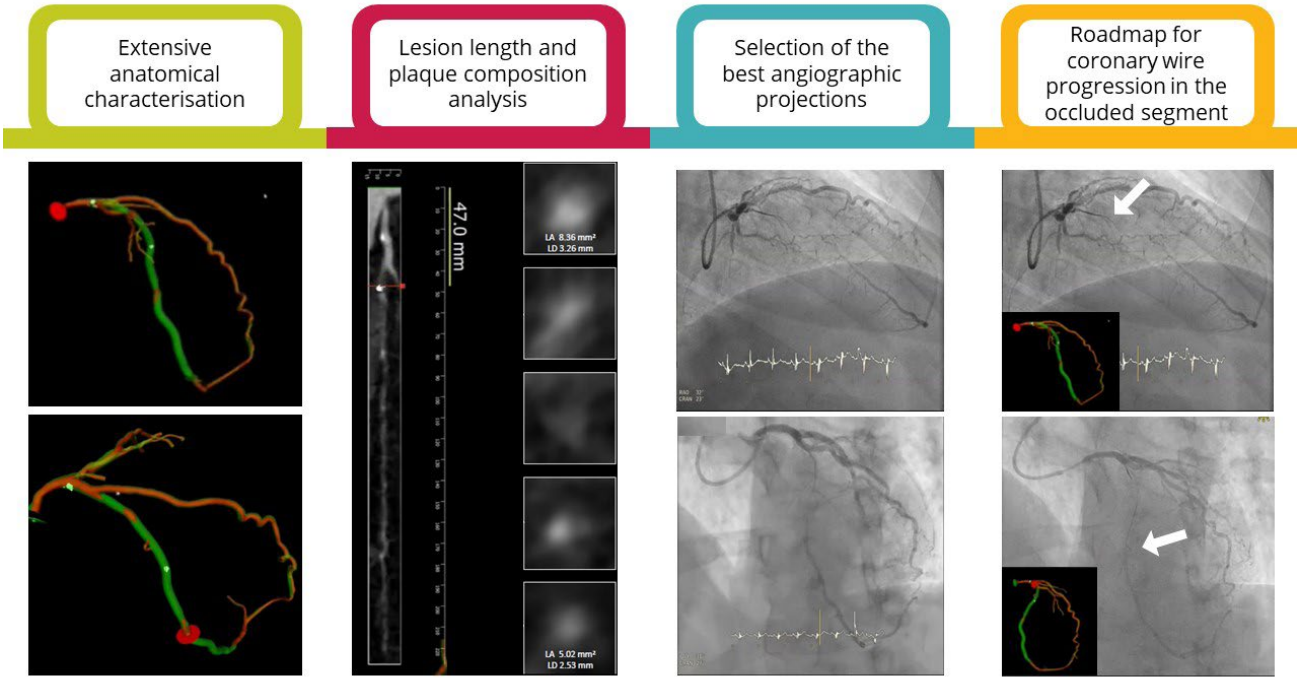
CCTA has been increasingly used worldwide to diagnose and rule out coronary artery disease.[23] In the context of CTO, CCTA has several potential applications beyond diagnosis, as it can be useful for prediction of procedural success, pre-procedural planning, and intra-procedural guidance (Figure 2).[24]

Firstly, CCTA-derived scores resulted to be even more accurate than the traditional angiography-derived J-CTO score (that considers proximal cap shape, calcification, bending >45 °, occlusion length, and previously attempted PCI) for successful CTO–PCI prediction.[25-27]

Secondly, providing deep insight into the anatomical architecture (e.g., calcification, tortuosity, length, and stump morphology), CCTA might guide best upfront strategy selection for revascularisation and likely improve the outcome.[28] Additionally, CCTA analysis can aid in preparing the material and catheterisation laboratory (cath lab), and in identifying the most suitable fluoroscopic projection views, complementing conventional angiography by a 3D model and real-time integration of CCTA data in the cath lab.[29]

Finally, CCTA offers the chance to integrate the anatomical characterisation with derived functional data by means of a specific software (HeartFlow, Mountain View, California, USA). Based on blood flow simulations using computational fluid dynamics, it is possible to derive FFR from CCTA. The recent development and clinical validation of the FFR_{CT} planner tool further enhances PCI planning potential, as it allows for virtual stenting of coronary stenoses and accurate prediction of post-PCI FFR, independent of the disease pattern, calcification, and image quality.[30] Nevertheless, the potential usefulness of CCTA to plan and guide interventional procedures in the CTO remains largely unexplored. The ongoing Precise Procedural and PCI Plan trial[31] will provide further evidence on this concept by comparing CT-guided PCI to intravascular ultrasound-guided PCI, also including a subset of CTO lesions.

Figure 2: The added value of coronary CT angiography in chronic total occlusion percutaneous revascularisation.



CCTA is a promising technology for enhanced CTO PCI planning and guidance as it allows for the extensive anatomical characterisation (e.g., occlusion length, tortuosity, stump morphology, angulation, calcification burden and cross-sectional area, and outlet and distal vessel morphology); the computation of pre-procedural FFR and prediction of PCI results; the identification of the best angiographic projection in the cath lab, minimising foreshortening and overlapping of the segment of interest; and the identification of the exact vessel trajectory and real-time integration of 3D CCTA data and fluoroscopic images in the cath lab, guiding coronary wire progression in the occluded segment (the white arrows are pointing the coronary wire tip).

Cath lab: catheterisation laboratory; CCTA: coronary CT angiography; CTO: chronic total occlusion; FFR: fractional flow reserve; PCI: percutaneous coronary intervention.

REDUCING METAL LAYERS IN CHRONIC TOTAL OCCLUSION–PERCUTANEOUS CORONARY INTERVENTION: IS LESS, MORE?

Despite the demonstrated long-term efficacy and safety of contemporary new generation drug-eluting stents,[32] total stent length, as well as the number of implanted stents, are procedural factors accounting for long-term risk of stent failure both in non-CTO and CTO–PCI.[33] Therefore, the potential for reducing metal deployment represents an attractive perspective to minimise late stent-related events and long-term antithrombotic therapy-driven complications. With this background, the implantation of fully bioresorbable scaffolds and the usage of drug-coated balloons were proposed to 'uncage' the coronary vessel wall. Concerning bioresorbable scaffolds, there is paucity of evidence on their use in the specific setting of CTO–PCI, with conflicting results,[34-36] thus preventing for drawing definitive conclusions.

In contrast, the use of drug-coated balloons has a number of potential treatment advantages supported by recent clinical data, with initial experiences reported also in the context of CTO–PCI.[37] In particular, a hybrid approach, with stenting of the CTO body and delivery of antiproliferative drug through drug-coated balloon inflation in the diseased distal vessel avoiding an additional metal layer, seems a promising strategy.

The ongoing Drug-Coated Balloon Coronary Angioplasty Versus Stenting for Treatment of Disease Adjacent to a Chronic Total Occlusion (Co-CTO) trial[38] will provide new clues in this regard, randomising 141 patients with a CTO eligible for PCI to a hybrid versus standard stenting strategy.

CONCLUSION

Thanks to the recent technical progress and the evolving expertise of dedicated operators, the success rate of percutaneous CTO revascularisation is steadily rising, accompanied by a decline in complication occurrence. Nevertheless, several challenges remain to be overcome to optimise procedural results and patient selection. In this regard, the integration of precise anatomical characterisation of the lesion, likely by CCTA, with physiological data, obtained either invasively or non-invasively, could be the key to further improvement. Future research and more robust evidence from randomised clinical trials are required to provide definitive guidance about the management and decision-making in the context of CTO–PCI.

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Vieussens' Arterial Ring with Coronary Artery Disease: Affecting Clinical Decision Making

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Abstract

Background:
Incidental findings on imaging are becoming increasingly common. An example of such a finding is a Vieussens' arterial ring. It was first described by Raymond de Vieussens as a collateral pathway between the conus branch of the right coronary artery and the proximal right ventricular branch of the left anterior descending coronary artery. This finding can be of significance in patients with coronary artery disease.

Case Presentation:
The authors present the case of a 79-year-old male who experienced atrial tachyarrhythmia with a complex coronary artery fistula between the left anterior descending artery, conus branch, and the main pulmonary artery, indicating a Type Ib Vieussens' arterial ring. Type Ib means that it is accompanied by vascular pathology. The patient also had additional coronary disease in the left anterior descending artery, further increasing the complexity of the case.

Conclusion:
Coronary collaterals offer an alternative source of blood supply in cases of additional coronary artery disease and can impact patient prognosis. Chronic myocardial ischaemia and increased shear stresses are causes of collateral circulations. Vieussens' arterial rings can be subdivided into four groups. Only one case report of a Type Ib Vieussens' ring has been identified on literature review, where the patient presented with a non-ST elevation myocardial infarction, unlike the atrial tachyarrhythmia in this case. Given their rarity, specifically of Type Ib, there is increased difficulty in establishing an appropriate management pathway, thus having great impact on clinical decision making.

Key Points

1. Coronary collaterals offer an alternative source of blood supply that can result in a prolonged period of myocardium viability in cases of original vessel failure or coronary occlusion.

2. Vieussens' arterial rings (VAR) are embryological remnants that can act as collateral circulation, and the rarity of VARs can lead to difficulty in establishing the most appropriate management of patients presenting with it.

3. VAR Type Ib is described as a VAR that is associated with a vascular pathology, such as a fistula or an aneurysm, which is the case in the reported patient.

BACKGROUND

CT coronary angiography (CTCA) has been increasingly used in the diagnosis of coronary artery disease. Incidental findings on imaging are becoming more common in medical practice.[1] The authors present a case of an incidental finding of a Vieussens' arterial ring (VAR).

VARs were first described by French anatomist Raymond de Vieussens. They are observed in the population mostly as an embryonic conotruncal ring remnant;[2] however, pathological VARs are very rare. It is widely described as a collateral pathway between the conus branch of the right coronary artery (RCA) and the proximal right ventricular branch of the left anterior descending coronary artery (LAD).[3-5]

This finding can be of significance in patients with coronary artery disease as it can be a means for cardiac perfusion. However, it is important to consider the implications of disease present in this collateral circulation when there is additional disease in the coronary arteries.[6]

CASE PRESENTATION

A 79-year-old male was admitted under the cardiology team with chest pain, shortness of breath, and palpitations. The patient reported a sudden onset of chest tightness, feeling clammy, and light-headed while walking 2 hours before presentation to their general practitioner. An ECG (Figure 1) performed by the patient's general practitioner revealed narrow complex tachycardia at 150 bpm, which failed to respond to Valsalva manoeuvres, and paramedics were called.

Physical examination was normal; blood pressure was 147/84. The patient was transferred to the local district general hospital and whilst en-route, 8 hours after symptoms onset, the patient's symptoms resolved, coinciding with self-cardioversion to normal sinus rhythm on the paramedic cardiac monitor.

No previous atrial tachyarrhythmias had been documented. However, the patient stated that a similar episode a few months ago had self-resolved. They had no significant past medical history and did not take any regular medication.

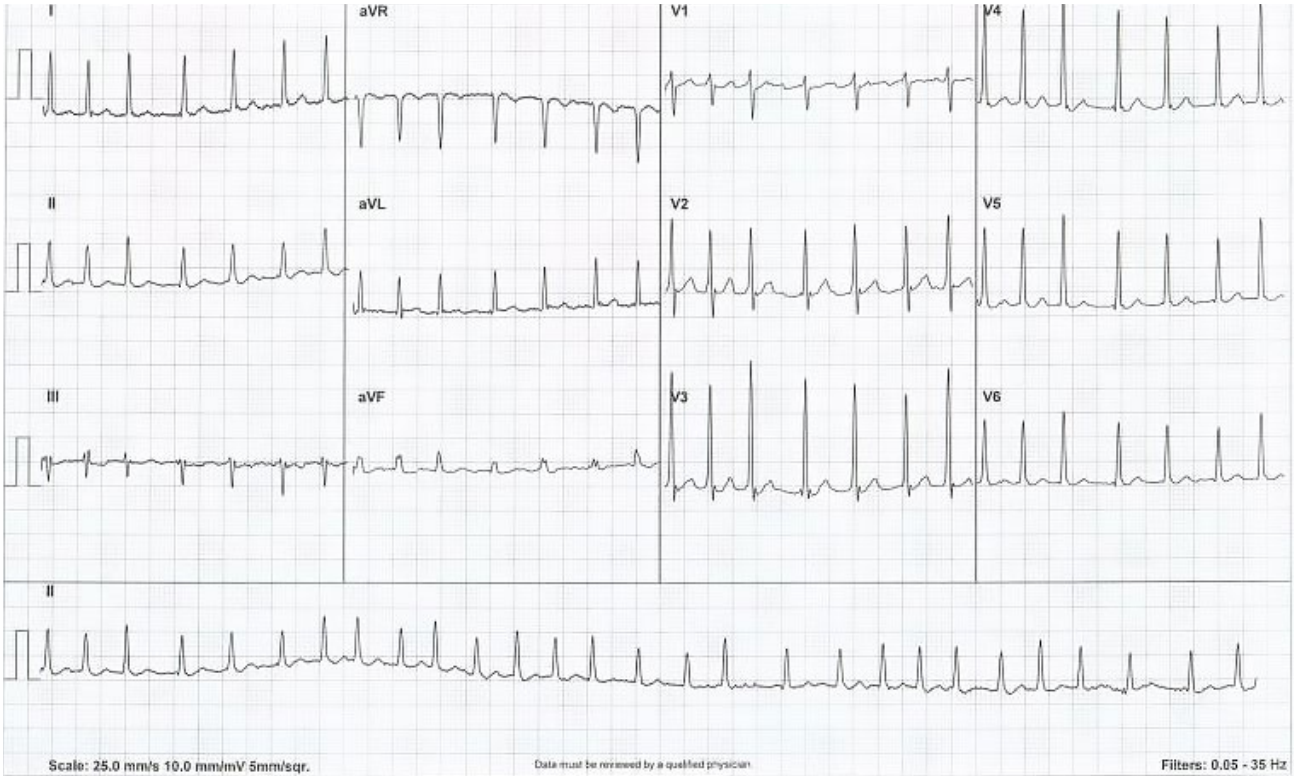
INVESTIGATIONS

Baseline investigations demonstrated normal full blood count, bone profile, renal profile, and thyroid function. Troponin I was elevated at 240 ng/L, but on repeat testing 3 hours later it had reduced to 117 ng/L (normal range: 0–34 ng/L).

Chest X-ray showed no abnormality. An ECG carried out at the emergency department, after ambulance crew handover, showed atrial fibrillation with a ventricular rate of 108 bpm.

A transthoracic echocardiogram to investigate possible aetiologies for atrial fibrillation revealed normal sized left and right ventricles with an ejection fraction of 55–65%, along with mild mitral regurgitation and mild-moderate tricuspid regurgitation.

Figure 1: ECG demonstrating a narrow complex tachycardia.



Troponin elevation was likely rate related but a CTCA was arranged as an outpatient to screen for the presence of atherosclerosis. A diagnosis of Type 2 myocardial infarction due to atrial fibrillation with rapid ventricular rate was diagnosed. The patient was anticoagulated, given the new diagnosis of atrial fibrillation with a novel oral anticoagulant, and started on a β-blocker for rate control.

CTCA images (Figure 2) demonstrated a complicated lesion of the vessels arising from the anterior aspect of the mid-LAD traversing across the anterior aspect of the pulmonary artery outflow origin with a small associated aneurysm (1 cm). Thereafter, there was also a connection to the ostial RCA conus branch. There was a small connection between the aneurysmal portion and the pulmonary outflow tract. This would be classified as a Type Ib VAR variant.

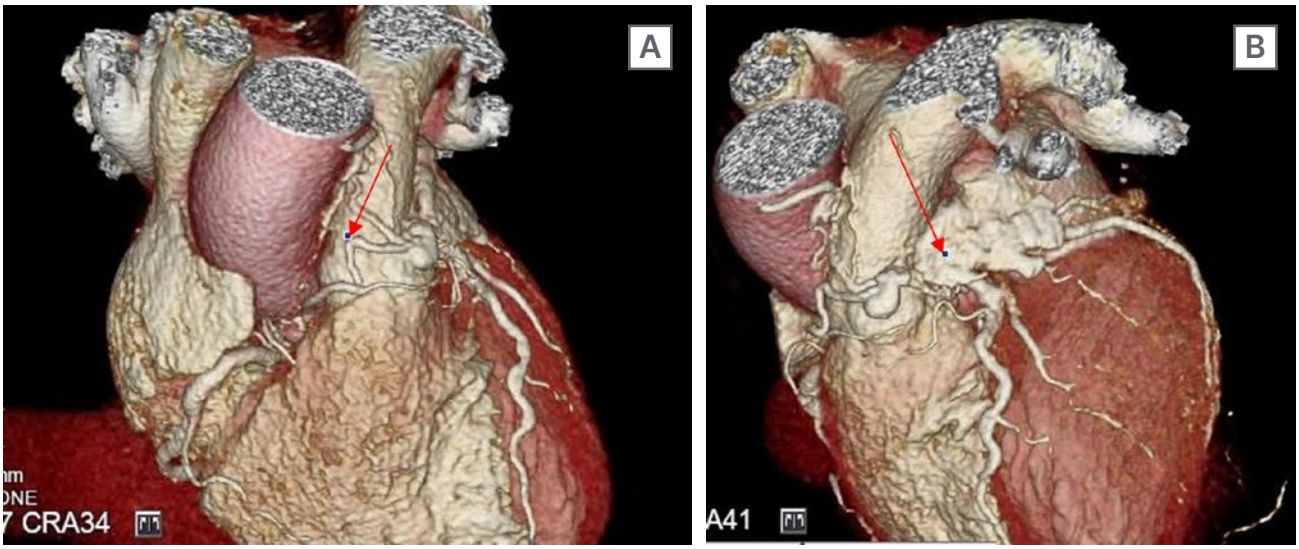
There were also two moderate stenoses in the LAD seen proximally, and a further possible moderate stenosis seen in the mid vessel. The circumflex demonstrated a calcified lesion in the mid vessel, which is remodelled with an underlying mild stenosis.

MANAGEMENT

The case was discussed at a local multidisciplinary imaging meeting and with a tertiary radiology team. The consensus opinion was that this abnormality was likely to be a prominent VAR that can be sub-defined as a Type Ib, which is associated with coronary disease and aneurysm/fistula.

A cardiac perfusion MRI was performed with adenosine, which demonstrated no significant late gadolinium enhancement (reflecting no significant previous infarct) and no inducible ischaemia (reflecting coronary circulation was satisfactory). It also demonstrated normal biventricular function. This case was rediscussed at interventional local multidisciplinary team meeting and consensus of outcome was for a conservative medical approach. A repeat ECG has been arranged to support decision making

Figure 2: A CT coronary angiography demonstrated an unusual complex coronary artery fistula between the left anterior descending artery, conus branch, and the main pulmonary artery.



There was also associated moderate stenosis of the left anterior descending artery.

whether a further rhythm strategy is required if the patient has remained in atrial fibrillation.

DISCUSSION

Coronary collaterals are anastomotic connections, without an intervening capillary bed, between portions of the same coronary artery and between different coronary arteries.[7] They offer an alternative source of blood supply when the original vessel fails and aid to reduce myocardial ischaemia during coronary occlusion. This may result in a prolonged period of myocardium viability following an acute myocardial infarction and, therefore, extends the period of time available until successful coronary reperfusion.[8]

Collateral circulation can develop as a consequence of chronic myocardial ischaemia stimulating biochemical signal release, including angiogenic growth factors and induction of the proliferation of smooth muscle cells, and an increase in shear stresses. In normal circumstances, the pressure in the right and left coronary systems is equal and there is no significant flow detected in the connection. However, when stenosis develops due to for instance atherosclerosis resulting in coronary artery disease, it results in the vessel dilating and allowing blood to flow.[7]

VARs are connections between the conus branch of the RCA and the proximal right ventricular branch of the LAD.[4,9] They were first described in literature by French anatomist Raymond de Vieussens in 1706, who provided their name to an identified proximally epicardial connection between the RCA and LAD. Unlike ischaemia-induced collateral vessels, they are embryological remnants that become clinically significant as an intercoronary collateral vessels in the context of coronary artery disease.[10]

According to Dogan et al.,[2] VARs can be subdivided into four variants, which are Ia: VAR with no accompanying vascular pathology ("classic VAR"); Ib: VAR with accompanying vascular pathology (aneurysm or fistula); II) VAR-like dual LAD duplication; and III) VAR with single coronary anomaly.

This is a rare case of a pathological VAR (Type Ib) and in Dogan et al.,'s[2] evaluation of 3,443 consecutive CTCA, no cases of Type Ib were detected. Managing coronary artery fistulas and aneurysms is a complex and challenging process

in itself, without the additional involvement of a VAR as an important variable in decision making. The authors would direct readers to the 2018 article 'Management of coronary artery aneurysms' for a comprehensive explanation of the decision making variables and processes involved when managing these findings.[11]

An internet literature review demonstrated only one case report of a Type Ib VAR in the context of a 55-year-old male presenting with non-ST elevation myocardial infarction, differing from the authors' case of a presentation with atrial tachyarrhythmia.[12] Given the rarity of this anatomical finding, there is no established guidance on approach to clinical management.

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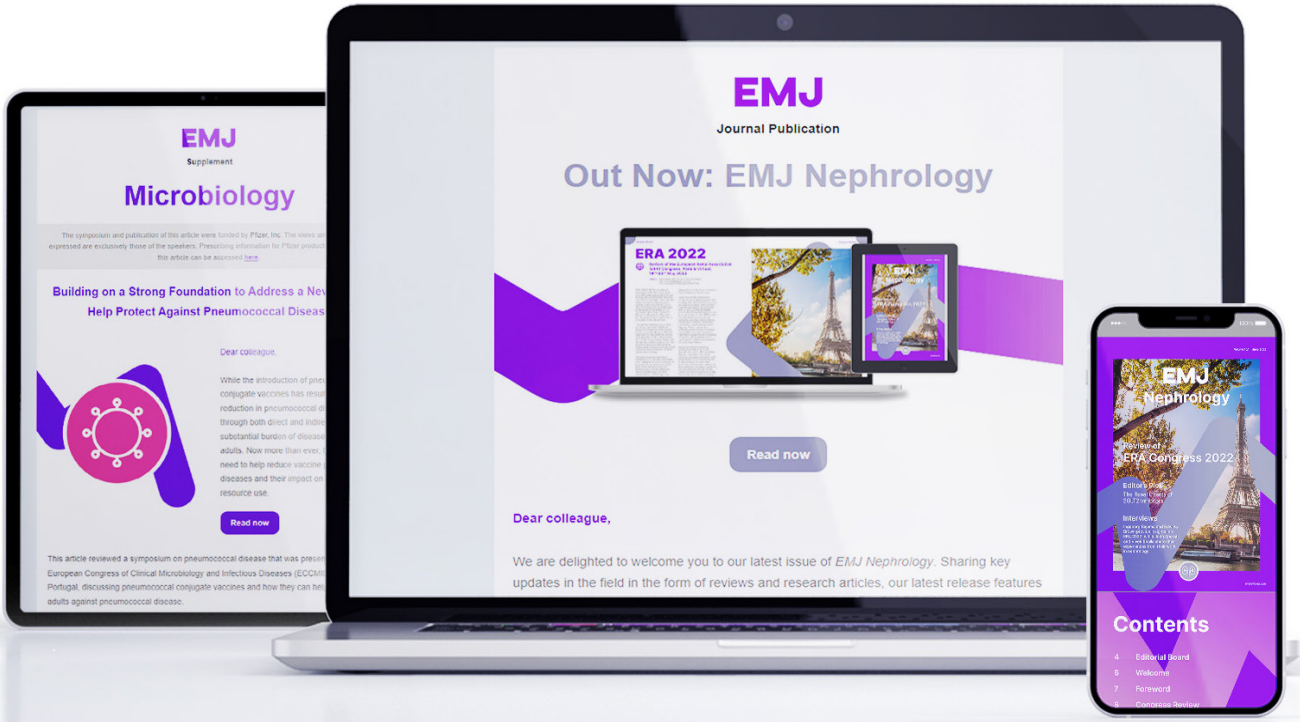

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