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CASE SERIES
Heart failure

Cardiac resynchronization therapy in patients with a coronary sinus reducer: a case series

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Background Reducing venous drainage of the coronary sinus is a promising intervention for refractory angina. Coronary Sinus Reducer (CSR) System™ effectively treats patients with refractory angina, possibly by increasing coronary collateral circulation, and leads to an improvement in their symptoms and quality of life. In patients with impaired left ventricular function and electrocardiographic dyssynchrony, cardiac resynchronization therapy (CRT) is an established treatment. However, there is only one published case report of CRT in a patient implanted with a CSR system. We present the first case series of CRT in patients implanted with the CSR system.

Case summary This case series describes three patients. The first case demonstrated that CRT is feasible in patients implanted with a CSR system. The second case is the first report of a left ventricular lead extraction after CSR, and the third case was complicated due to the patient's medical history; however, CSR system implantation was feasible without major complications.

Discussion Our results suggest that CRT is feasible in patients implanted with a CSR system, and lead extraction after CSR system implantation is possible. However, lead extraction in cases of severe adhesions around the CSR system and the coronary sinus may be associated with a high risk of complications; alternative options should be discussed at an early stage.

Keywords Cardiac resynchronization therapy • Coronary sinus reducer • Lead extraction • Coronary collateral circulation • Refractory angina • Case series

ESC curriculum 5.11 Cardiac resynchronization therapy devices • 3.3 Chronic coronary syndrome

Learning points

- Left ventricular lead extraction after coronary sinus reducer (CSR) implantation is feasible but risky and should be performed in tertiary centres with lead extraction experience and surgical backup.
- Missing backup via delivery sheath can occur in complex coronary sinus anatomy due to difficulties in advancing the delivery sheath through the CSR.
- However, passage of the CSR via delivery sheath is possible.

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Introduction

The Coronary Sinus Reducer (CSR) System™ (Neovasc, Canada), along with optimal drug therapy, leads to a marked improvement in the symptoms and quality of life of patients with refractory angina.[1] A possible mechanism underlying this intervention may involve an increase in coronary collateral circulation with a redistributed epicardial blood flow that is less affected by ischaemia and the ischaemic endocardium.[1,2]

Summary figure

Patient 1
2007 – CABG **06/2016** – PCI **04/2019** – PCI (restenosis) **06/2019** – Chronotropic incompetence, left bundle branch block (QRS duration 160 ms) and refractory angina **07/2019** – CSR implantation **01/2020** – PCI **01/2020** – CRT-ICD implantation (LV-EF 30%, optimal medical therapy) **11/2022** – TAVR (transfemoral aortic valve replacement)
Patient 2
05/2001 – CABG **2015** – Multiple PCIs with restenosis and refractory angina **02/2017** – CRT pacemaker implantation **08/2021** – CSR implantation and dislocation of the LV lead **11/2021** – LV-lead revision with extraction and reimplantation
Patient 3
02/2002 – Prosthesis due to infrarenal aortic aneurysm **05/2018** – Failed endovascular exclusion of the abdominal aortic aneurysm with complicated course (several revisions with laparotomy due to intraabdominal bleeding; abandoned delivery system) **10/2018** – Micro vessel disease with therapy refractory angina and non-relevant stenosis of the right coronary artery **07/2019** – CSR implantation **09/2020** – Axillo-femoral bypass due to symptomatic peripheral artery disease **07/2022** – PCI with perforation of the RCA **07/2022** – Occlusion of a persistent foramen ovale due to relevant right-to-left shunt with consecutive revisions (2) due to small occluder size **09/2022** – CRT P implantation with surgical preparation of the v. axllaris after pneumothorax and malpunction of the axillary vein within the first attempt

Myocardial ischaemia is among the most prevalent causes of impaired systolic left ventricular (LV) function and other ischaemia-associated bradyarrhythmias. In such patients, cardiac resynchronization therapy (CRT) has become an established and effective therapy.[3,4]

Only one case report has been published featuring successful CRT in a patient implanted with a CSR system.[5] The present case series illustrates that, in addition to standard implantation, extractions are also possible in patients with a CSR system, even in the presence of multiple other cardiac devices.

Patient 1

A 68-year-old man with a history of severe coronary three-vessel disease, multiple coronary interventions, and coronary artery bypass grafting 14 years ago was implanted with a CSR system for angina pectoris [Canadian Cardiovascular Society (CCS) class III] 16 months ago. His symptoms subsequently improved to stable angina pectoris CCS I–II. Due to a highly impaired systolic LV function, an electrocardiographic left bundle branch block, QRS duration of 160 ms, and dyspnoea New York Heart Association (NYHA) class III, the indication for CRT was confirmed 1.5 years after CSR implantation.

During CRT, the LV lead was relatively easily advanced through the CSR using a guidewire (*Figure 1A*); even the 9 F delivery sheath could be advanced over the reducer (*Figure 1B*). A venogram with the 9 F delivery sheath in place showed a markedly reduced venous backflow over the reducer (*Figure 1C*). A hydrophilic guidewire was then advanced into a posterolateral side branch of the coronary sinus (CS) (*Figure 1D*), and the LV lead (Sentus pro MRI quadripolar 5 F; Biotronik, Berlin, Germany) was placed in a wedge position, resulting in excellent thresholds and significant shortening of the QRS duration (QRS: 105 ms; *Figure 1E*). The CRT implantation was successful, and the patient showed an improvement in dyspnoea from NYHA III to NYHA I–II after 3 months.

This first case demonstrated that CRT is feasible in patients with CSRs. Additionally, 5 F diameter LV leads did not result in total occlusion of the CS and still showed a preserved (although reduced) flow, even with a 9 F delivery sheath.

Patient 2

A 78-year-old man with a history of severe coronary artery disease, recurrent interventions, in-stent restenosis, and bypass surgery

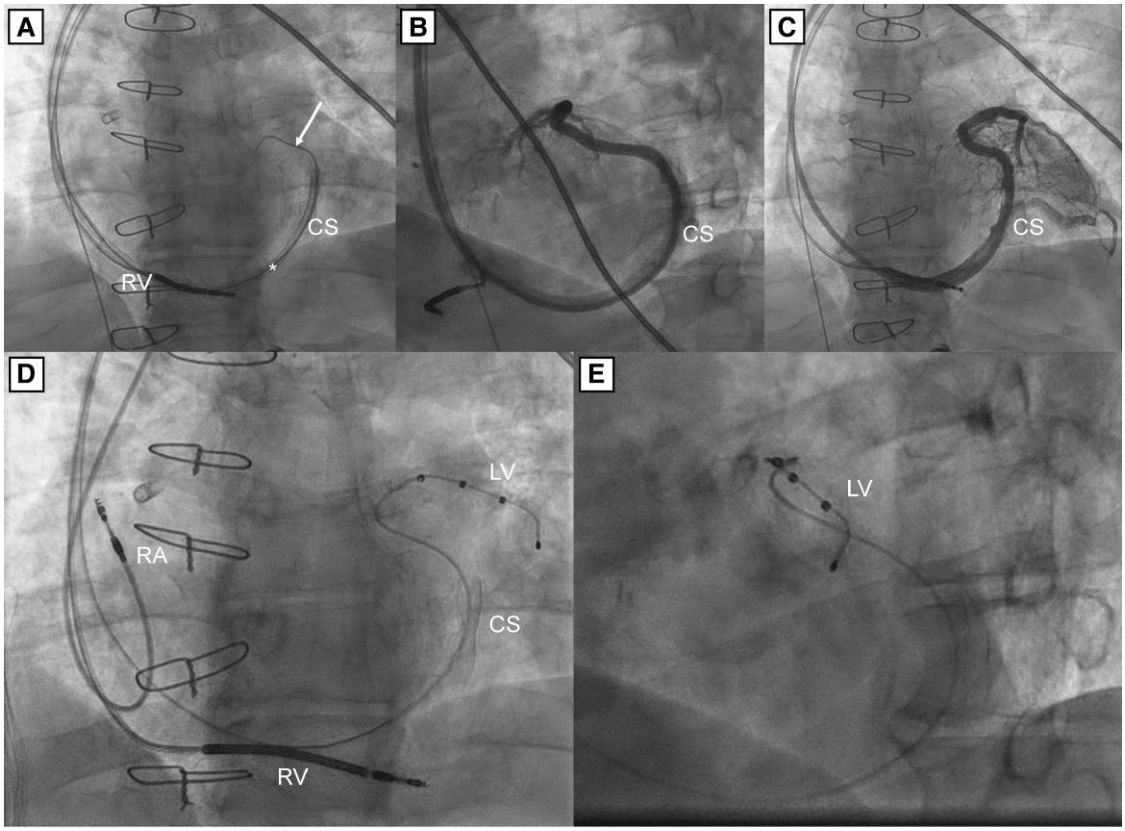

Figure 1 (*A*) The CSR is passed using a guidewire (arrow) and a 9 F Biotronik (9 F; Berlin, Germany) delivery sheath (marked with *). The RV ICD lead is located in the inferoseptal region (RV). The CSR is passed by the delivery sheath (CS). (*B* and *C*) Angiogram of the CS via the 9 F delivery sheath that passes the CSR shows no significant obstruction. (*D*) Anterolateral LV lead placement over the delivery sheath that is pulled back to the beginning of the CSR. The RV ICD and right atrial leads are located in the right atrial appendage. (*E*) Final anterolateral LV lead position; the posterolateral side branch is not suitable due to phrenic capture. CS, coronary sinus; CSR, coronary sinus reducer; ICD, implantable cardioverter defibrillator; LV, left ventricular lead; RV, right ventricular lead.

underwent CSR implantation in August 2021 for treatment-refractory angina (CCS III). The patient already had a CRT-pacemaker *in situ* that was implanted in February 2017, 52 months before the CSR procedure (*Figure 2A*). Optimally, the CSR system is implanted before possible CRT. However, in this case, the patient developed symptoms later in life, and the availability of an invasive therapy for refractory angina pectoris was not present at the time of CRT.

During the implantation of the CSR system, the pre-existing LV lead became dislocated. This was unexpected, especially as the device had been *in situ* for more than 4 years, and the LV lead was presumed to have already adhered to the target vessel and the main CS, necessitating revision (*Figure 2B*). Additionally, complications arose as the LV lead became trapped between the vessel wall and the CSR, posing a high risk of injury (rupture) in the CS during revision (planned extraction).

Efforts were initially made to reposition the trapped LV lead into a target vessel using a guidewire. However, this approach proved unsuccessful. Consequently, manual traction was employed with care, resulting in the successful extraction of the lead without any complications or dislodgment of the CSR (*Figure 2C*).

Subsequent reimplantation followed a procedure similar to that in the first case. However, placing the 9 F delivery sheath over the CSR proved unfeasible (*Figure 2D and E*). Nevertheless, the quadripolar LV lead (Quartet™, Abbott Medical, St Paul, MN, USA) was advanced over the CSR and precisely positioned in a posterolateral target vein using the guidewire. The procedure concluded smoothly without complications, showcasing the successful removal of a trapped LV lead, 4 years and 2 months after CSR implantation.

This case represents the first report of LV lead extraction following CSR implantation, demonstrating the feasibility of the procedure without major drawbacks. However, it is crucial to acknowledge the potential risks associated with lead extraction in cases involving severe adhesions around the CSR and CS. Therefore, proactive consideration of alternative options and early discussions are essential to ensure optimal outcomes while minimizing potential complications. Another issue to consider in this case is that it is not always possible to advance the 9 F delivery sheath through the CSR system. This can lead to a lack of backup for LV lead placement due to the proximal location of the CSR in the CS, making optimal CRT or advancement of the LV lead into the target vessel challenging.

Patient 3

This case describes an 83-year-old man with multimorbidity and a substantial history of interventions, operations, and complications. The patient had symptomatic binodal disease with impaired systolic LV

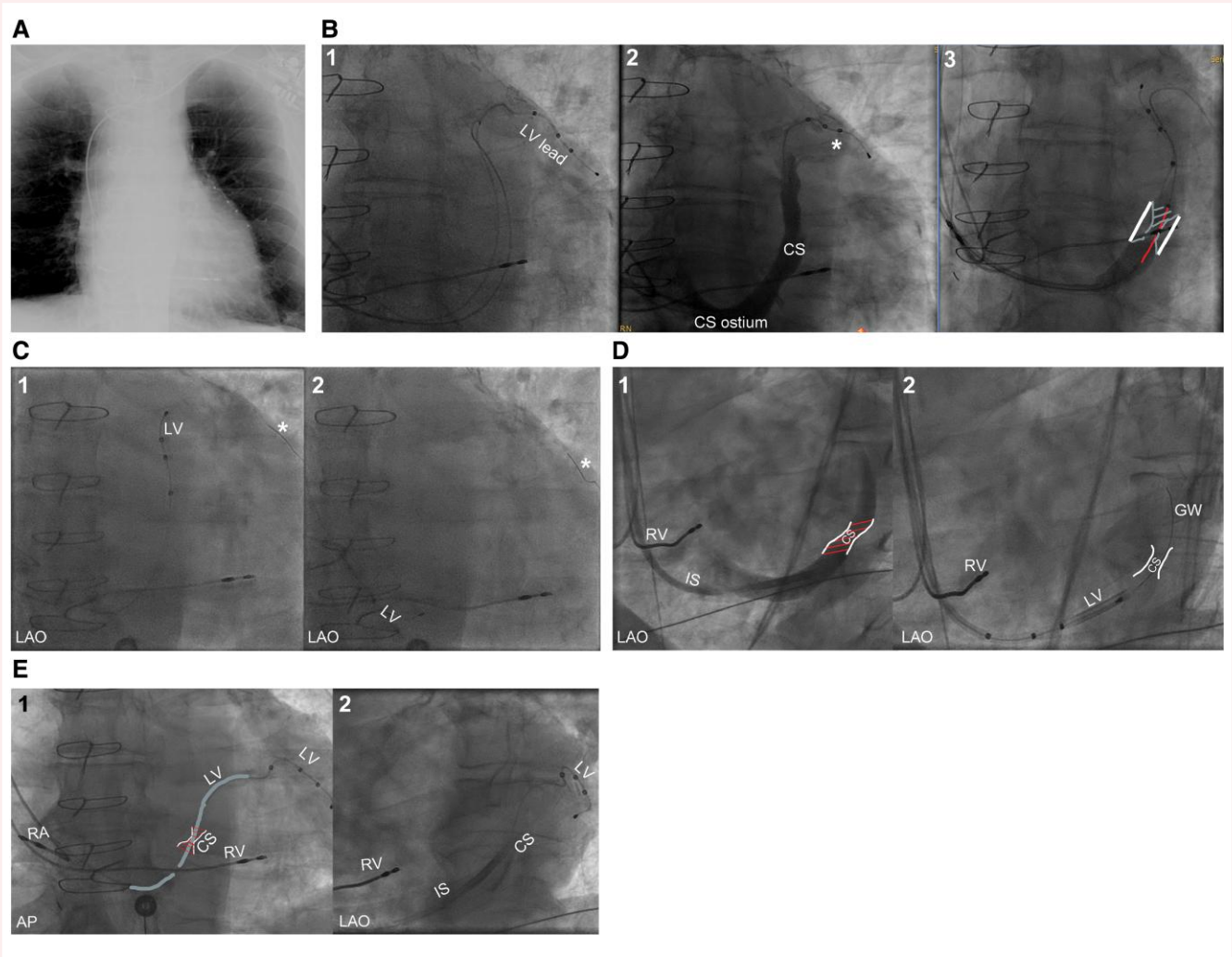

Figure 2 (*A*) Radiograph after CSR implantation 52 months before CRT. (*B*) Implantation of the CSR with (1) dislocation of the LV pacemaker lead (marked with *) (2) within the procedure. Finally (3), the lead is dislocated into the main CS and fixed between the reducer (X) and endothelium of the CS. (*C*) (1) Guidewire with intention to relocate the LV lead in the initial target vein (LV) (marked with *). (2) Retraction of the trapped LV lead with manual traction without any relevant dislocations and complications due to challenging repositioning of the LV lead. (*D*) (1) Cannulating the CS with the IS and illustration of the coronary sinus with contrast medication showing the stenosing effect of the CSR (CS). Right ventricular lead (RV) placed inferoseptally. (2) After cannulating the coronary sinus passage of the CSR via guidewire (GW) and advancement of the LV lead (LV) to the end of the IS. (*E*) (1) AP view with the LV lead (LV) advanced over the CSR (CS) into the target vein (lateral); right atrial lead (RA) located laterally. (2) LAO view showing the laterally placed LV lead and IS located at the beginning of the CSR. AP, anterior posterior; CS, coronary sinus; CSR, coronary sinus reducer; IS, introducer sheath; LAO, left anterior oblique; LV, left ventricular lead; RV, right ventricular lead.

function and high right ventricular pacing requirements for which a CRT-pacemaker was indicated. Implantation was complicated in this patient primarily due to his medical history, particularly as he had an aneurysm in the ascending aorta (5.3 cm in size), a non-eliminated abdominal aortic aneurysm (7.4 cm in size), and a so-called suspender bypass (arterial bypass graft of the right axillary artery to the femoral dexter artery, demonstrated by computed tomography and radiography; *Figure 3A* and *B*). While attempting to treat the abdominal aortic aneurysm via stenting and exclusion, the entire introducer of the stent could not be retracted; therefore, it had to be retained (*Figure 3B*). Additionally, the patient had severe coronary artery disease with a history of percutaneous coronary intervention and a symptomatic patent foramen ovale with pressure equalization; therefore, after a CSR system implantation (July 2019), closure of the symptomatic patent foramen ovale (July 2022) was also performed.

All these procedures were associated with peri- and post-procedural complications. In the first attempt, the procedure had to be discontinued due to access problems and rescheduled. During the second attempt, the axillary vein was dissected under visualization by vascular surgery (axillary access), and this was accompanied by major venous bleeding in the presence of drastically increased venous pressure. After the creation of venous access, intubation of the CS with the passage of the EP catheter (Biosense Webster; Irvine, CA, USA) over the constriction of the reducer was successful without complications (*Figure 3C*). Nevertheless, the backup of the delivery sheath was markedly reduced due to the surgical access (axillary vein), and the venous

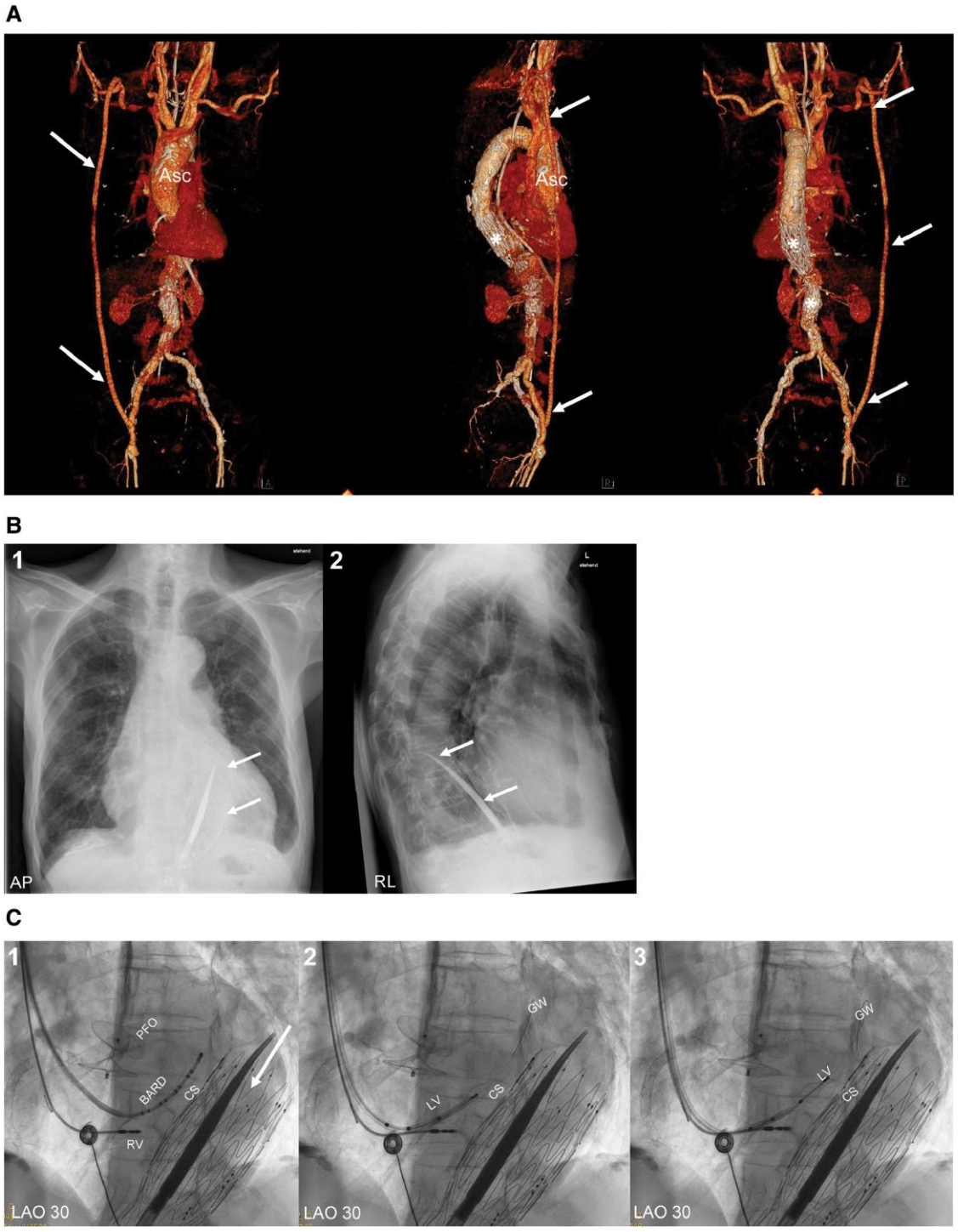

Figure 3 (*A*) Computed tomography showing the aneurismatic dilated aorta ascendens (Asc), bypass via a right subclavial vein to a femoralis communis (arrows), and proximal and distal parts of the non-fully expanded intra-aortic stent in the abdominal aorta (*). (*B*) Chest radiograph before CRT implantation showing the abandoned intra-aortic stent with the trapped introducer tools (arrow). (*C*) (1) Cannulating the CS with the steerable catheter (BARD), PFO occluder (PFO), abandoned intra-aortic stent (arrow) passing the CSR (CS), and RV lead (RV). (2) The LV lead (LV) is still in the IS located in front of the CSR, and the guidewire (GW) placed in the main coronary sinus. (3) Advancing the LV lead through the CSR. (*D*) Guidewire (GW) advanced into the target vein (posterolateral), with the LV lead being pushed over the guidewire into the final posterolateral position—marked with arrows (1 and 2). (*E*) Final result, atrial lead (RA) located antero-laterally, right ventricular lead (RV) inferoseptally/apically and left ventricular lead (LV) through the CSR (CS) within the posterolateral side branch of the CS together; PFO occluder marked with *, a stented right coronary artery and the abandoned aortic stent with the introducer marked with an arrow. CS, coronary sinus; CSR, coronary sinus reducer; IS, introducer sheath; LV, left ventricular lead; PFO, patent foramen ovale; RV, right ventricular lead.

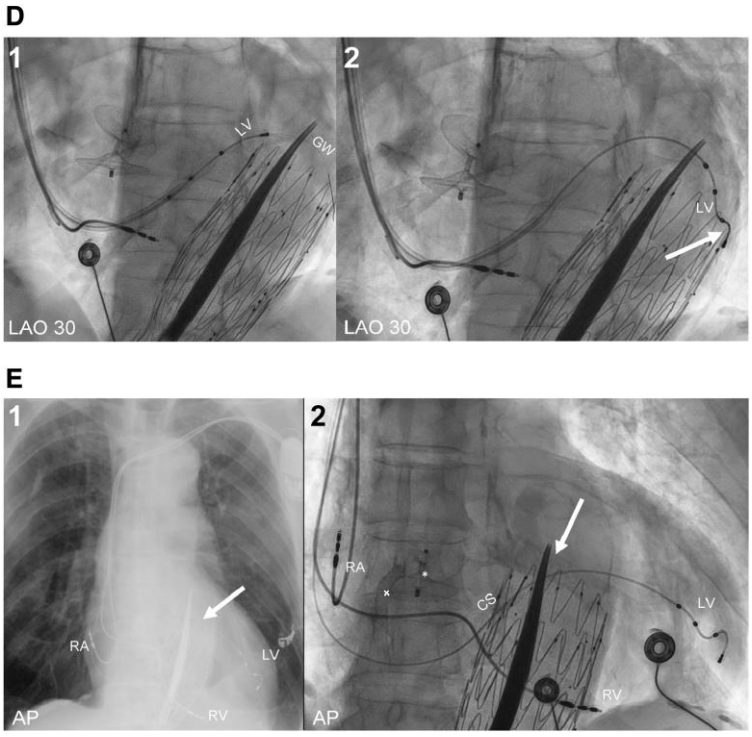

Figure 3 Continued

ligature of the vessel made it very difficult to guide the catheter without rebleeding in the area of the venotomy. However, the delivery sheath could only be advanced to the proximal CSR portion, and this meant relatively little support for lead placement when it was placed distally. The guidewire and LV lead (Sentus QP 85; Biotronik) were advanced over the narrow portion of the CSR, and the LV lead was placed in a posterolateral vein of the CS. With robust measurements and qLV delay, the lead was left in place, and the atrial and ventricular leads were placed in position (*Figure 3D*). The entire procedure was highly complicated due to the far lateral (axillary) venous access and extensive venous haemorrhage (*Figure 3E*). Supplementary material online, *Figure S1* demonstrates the theoretical feasibility of the implantation of a CSR system.

Nevertheless, this case demonstrates that it is possible to advance an LV lead over the CSR, even in multimorbid patients with pre-existing complications. However, depending on the position, support by the delivery sheath may be missing, and passage of the CSR with this sheath is not always possible.

Discussion

Coronary sinus reducer therapy is currently not included in any guidelines; however, recent study data are promising, especially for patients with refractory angina for whom a CSR system is the last option to reduce symptoms.

Besides the fact that a certain percentage of patients with coronary artery disease require CRT, the possible implantation of a CSR system should be discussed in advance if it is advisable to prioritize CSR implantation over CRT as a trapped LV lead requiring an extraction poses a significantly higher risk for major complications than an electrode placed through the CSR. In case of LV lead entrapment or dislocation after CRT and CSR, other options such as conduction system pacing (His bundle pacing or left bundle area pacing) or surgical interventions (removal of the LV lead under sight or epicardial LV lead) should also be discussed within a heart team.

Compared to the published case report,[5] we were able to pass the CS reducer once with the delivery sheath; however, this was not successful in the remaining two patients and may have caused difficulties in the final placement of the LV lead, as there may have been a lack of backup through the delivery sheath. An alternative would have been the passage of the CSR with a sub-selection catheter that has a smaller lumen; however, this can lead more frequently to CS dissections. Nevertheless, these options have not been attempted in the published literature.

The question of response to treatment in patients with a CSR system who have subsequently received CRT remains to be clarified because it can be assumed that the venous pressure in the CS continues to increase due to further obliteration caused by the lead. Theoretically, this could result in a marked reduction in angina and possible improvement in exercise capacity with CRT. Simultaneous use of the CSR system is not a limitation of CRT, and LV lead extractions were found to be feasible in patients after CRT and CSR implantation; however, a stepwise approach (first CSR implantation and then CRT) is suggested and has to be discussed in advance within a heart surgery team for management of patients with a high potential of therapy-refractory angina or patients with known severe coronary artery disease.

This case series provides evidence for the feasibility of CRT implementation in patients implanted with a CSR system and for LV lead extraction post-CSR implantation. The case of Patient 2 demonstrates that LV lead extraction is possible even after 4 years of CSR implantation, highlighting the potential risk of CS rupture and the need for such procedures to be performed in tertiary centres with surgical backup and expertise in lead extractions. These findings support the use of

CRT in patients implanted with a CSR system and suggest that lead extraction should be considered as a viable option, although the potential risks associated with severe adhesions should be carefully evaluated.

Lead author biography

Christian Grebmer obtained his medical degree from the Medical University of Graz in Austria and a PhD from the Technical University of Munich. During his seven-year subspecialization training in electrophysiology and cardiac device therapy at the German Heart Center in Munich, he worked under the supervision of Profs. Isabel Deisenhofer and Christof Kolb.

Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports* online.

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Data availability

The data underlying this article are available in the article and in its online *supplementary material*.

Ethics approval

The study was approved by the ethics committee of the University of Lucerne and was performed in accordance with the Declaration of Helsinki.

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