https://doi.org/10.35336/VA-1220

TRANSVENOUS LEADS EXTRACTION IN CHILDREN: A CASE SERIES

S.A.Aivazian[1], A.N.Shamatolskiy[2], A.V.Zakrevskiy[2], E.A.Mironov[2], M.V.Ryzanov[2], A.L.Maximov[2]

[1]Federal Budgetary «Health Institution Volga District Medical Center» of the FMBA, Russia, Nizhny Novgorod, 2 Nizhnevolzhskaya nab.; [2]State Budgetary Healthcare Institution of Nizhnevolzhskaya region «Research Institute - Specialized Cardiosurgical Clinical Hospital named after Academician B.A. Korolev», Russia, Nizhny Novgorod, 209 Vaneeva str.

Case series of four lead extraction procedures is described in this article. In all cases, indications for transvenous leads extraction were lead dysfunction. There were no complications of procedure.

Key words: cardiac pacing; transvenous lead extraction; children

Conflict of interest: none.
Funding: none.
Received: 22.06.2023 **Revision received:** 21.09.2023 **Accepted:** 28.09.2023
Corresponding author: Sergey A. Aivazian, E-mail: sergei_aivazyan@mail.ru

S.A.Aivazian - ORCID ID 0000-0002-9642-9754, A.N.Shamatolskiy - ORCID ID 0000-0003-2453-9257, A.V.Zakrevskiy - ORCID ID 0009-0003-7629-9096, E.A.Mironov - ORCID ID 0009-0006-8570-5510, M.V.Ryazanov - ORCID ID 0000-0002-3923-7174, A.L.Maximov - ORCID ID 0009-0008-8793-1348

For citation: Aivazian SA, Shamatolskiy AN, Zakrevskiy AV, Mironov EA, Ryzanov MV, Maximov AL. Transvenous leads extraction in children: a case series. *Journal of Arrhythmology.* 2024;31(1): e27-e33. https://doi.org/10.35336/VA-1220.

Among patients with implanted pacemakers and cardioverter-defibrillators, children account for less than 1%. This is a distinct group of patients whose treatment strategy differs from the adult population [1, 2] due to anatomical features, continued growth and high physical activity. When the device is implanted, the child knows that the electrode will need to be replaced in the future. The experience of implantation in children has shown that the main causes of stimulation failure in them are the growth of stimulation threshold and electrode fractures [3]. In children weighing less than 15 kg, epicardial implantation of single-chamber devices is recommended, but in some cases electrodes are implanted endocardially [2]. In such patients, obstruction of the veins through which the electrodes are implanted becomes a significant problem later on, and delayed non-functioning electrodes lead to adverse consequences in the long term [4-6]. Only a few papers have been published on the problem of transvenous electrode extraction (TREE) in children [7-12]. These papers reviewed the use of manual traction, traction with a locking stylus, propylene and metal dilators, electrosurgical dissection with the PERFECTA device, rotary dilators and laser, and femoral access extraction.

The aim of this paper is to share our first experience with TREE in children (Tables 1 and 2).

Clinical case 1

Boy, 13 years old, body mass 44 kg, height 162 cm. Primary implantation of a dual-chamber Adapta S pacemaker (Medtronic, USA), 5076 CapSureFix Novus electrodes (Medtronic, USA) into the right atrial appendage

Table 1.

Patient characteristics

Item #	Sex	Age, years	Weight, kg	Age of PI	Indication for pacing	Etiology of CRD	AP	Pacing mode	AE	VE	AVO
1	m	13	44	9 years	AVB 3 st	Unknown	no	DDDR	MDT 5076	MDT 3830	no
2	m	11	33	2 years 7 months	AVB 3 st	Myocarditis	no	DDDR	MDT 3830	MDT 3830	RMV
3	f	6	21	2 years 4 months	AVB 3 st	Congenital	no	DDDR	MDT 5076	MDT 3830	LSV
4	f	11	50	2 years 5 months	AVB 3 st	AC CHD	DS	VVIR	-	MDT 3830	no

Note: hereinafter PI - primary implantation; CRD - cardiac rhythm disorder; AP - associated pathology; VE - ventricular electrode, AE - atrial electrode; AVO - access vein occlusion; AVB - atrioventricular block; RMV - right marginal vein; LSV - left subclavian vein; DS - Down syndrome; AC CHD - after correction of congenital heart disease.

and 3830 SelectSecure electrodes (Medtronic, USA) into the right ventricle in the interventricular septum was performed for complete atrioventricular (AV) block at the age of 9 years. As the patient grew, the ventricular electrode (VE) tightened, increasing the stimulation threshold from 2.0 V to 4.0 V. Four years after the initial implantation due to th pacemaker battery exhaustion, the patient underwent implantation of a new Adapta DR pacemaker and a new 5076 CapSureFix Novus electrode (Medtronic, USA) into the right ventricle. The old 3830 SelectSecure electrode (Medtronic, USA) was isolated from the fusion and removed by simple manual traction without complications.

Clinical Case 2

Boy, 11 years old, weight 33 kg, height 150 cm (Figure 1a). At the age of 2 years and 7 months, endocardial implantation of a dual-chamber pacemaker Adapta S (Medtronic, USA) was performed for complete AV blockade. A 3830 SelectSecure atrial electrode (AE) (Medtronic, USA) was implanted in the right atrium. The 3830 SelectSecure VE (Medtronic, USA) was implanted in the interventricular septum. The system was implanted on the right side through the subclavian vein, as subclavian vein puncture could not be performed on the left side. Seven years later, a scheduled replacement of the pacemaker with an Enstura DR pacemaker (Medtronic, USA) was performed. Two years later - marked weakness, decreased pulse to 40 per min. Electrocardiogram shows impaired ventricular stimulation. It should be noted that the boy is right-handed and has been practicing big tennis. Multispiral computed tomography of the heart with contrast was performed during the preoperative examination. VE fracture was suspected. Occlusion of the right subclavian and unnamed veins was detected and a thrombus on the VE was suspected. Surgery was scheduled, but a positive test for COVID-19 was obtained. The patient was transferred to the observation ward for observation and treatment, anticoagulants (apixaban 5 mg x 2 times) were prescribed. After receiving a negative test for COVID -19, a transesophageal echocardiography (TE echocardiography) was performed and no thrombus or vegetations were detected in the right heart. Three surgical treatment options are discussed:

- *implant a new system on the left, attempt to remove the electrodes on the right with manual traction, if unsuccessful, leave the electrodes in place and seal them;*
- *perform conduction recanalization of the right unnamed vein, implant a new VE through an intra-roducer inserted behind the occlusion, try to remove the old electrode by manual traction, in case of unsuccessful traction the electrode should be left and sealed;*
- *perform TREE with the TightRail device (Spectranetics, USA), recanalize the right ring vein with the device, insert a conductor through the device lumen, and then implant a new electrode through the intraductor.*

Balloon angioplasty of the occluded vein was not supposed to be performed because the child had no clinical manifestations of venous insufficiency of the right upper

Table. 2.

Indications for TREE and surgical results

Item #	Indication for TREE	Number of REs, n	Age of RE, years	TREE risk[1]	TREE risk[2]	Method of extraction	ClS TREE	CS TREE	Complications of TREE
1	High ST	1	4	1	Tr	MT	yes	yes	no
2	VE fracture	2	9	1	Tr	PE - MT, VE - TightRail	yes	yes	no
3	High ST	2	4	1	Tr	PE - MT, VE - TightRail	yes	yes	no
4	ED	1	10	1	Tr	TightRail + EnSnare trap FmA + VT	yes	yes	no

Note: TREE - transvenous electrode extraction; RE - removed electrodes; [1] - EROS scale; [2] - SAFETY TLE calculator; ClS - clinical success; CS - complete success; ST - stimulation threshold; Tr - transitional; MT -manual traction; ED - electrode dislocation; FmA - femoral access; VT - venotomy.

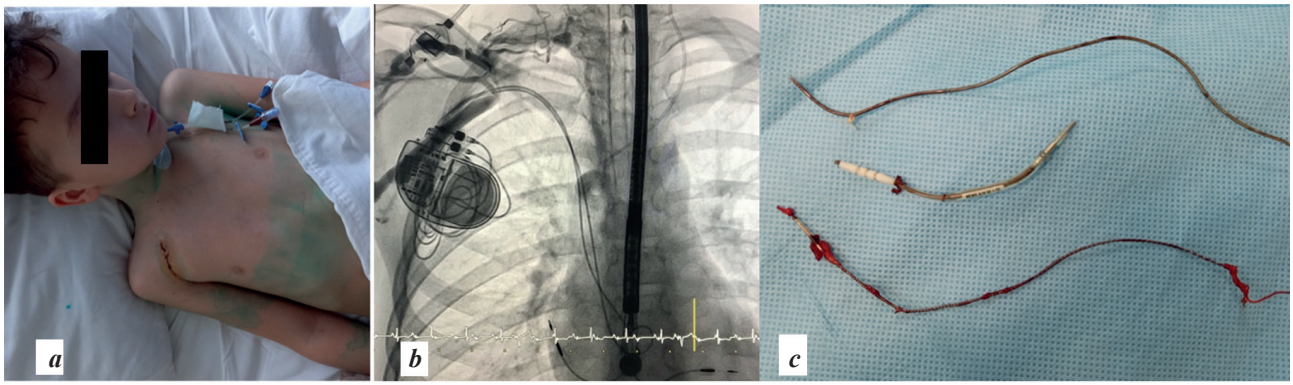

Fig. 1. Patient after transvenous electrode extraction, where a - patient's photo, b - phlebogram through the cubital vein (occlusion of the subclavian and unnamed veins on the right side was confirmed), c - removed electrodes.

extremity, and the probability of vein reocclusion before the next electrode implantation is extremely high.

Given the lack of experience with TREE in children, it was decided to attempt guidewire recanalization of the right unnamed vein. Implantation of the new system on the left side was also decided against, so as not to compromise the left side.

Surgery under inhalation anesthesia. Invasive blood pressure monitoring via the left radial artery. T- echocardiogram for continuous ultrasound monitoring of surgery. Two 5 Fr introducers were placed in the right femoral vein. An electrode for temporary pacemaker was passed through one of them into the apex of the right ventricle. Phlebography was performed through the right cubital vein, and occlusion of the subclavian and unnamed veins on the right side was confirmed (Fig. 1b). The postoperative scar was excised. The electrodes are disconnected from the device. A puncture of the right axillary vein was performed. A 5 Fr intra-roducer was placed in the vein. Attempted antegrade recanalization of subclavian and unnamed veins with Command 0.014» (Abbot, USA) and Roadrunner 0.035» (Cook, USA) guides on Multipurpose catheter (Merit, USA) without success. Attempted retrograde recanalization through the femoral vein with the same instrument also without success. It was decided to perform a TREE. With electrocoagulator, the VE was isolated from the scar tissue to the site of entry into the subclavian vein. Fracture of the conductive core under the fixing sleeve was detected. Given the design features of the electrode, the use of a locking stiletto was not possible. The electrode is lengthened with two 0 silk ligatures. The TREE of the VE was performed using the TightRail 9 Fr device (Spectranetics, USA). Two 0.035» metal conductors were inserted through the device lumen into the inferior vena cava. AE dislocation occurred during the removal of the VE. The electrode was removed by manual traction (Fig. 1c). Hemodynamics remained stable. There was no fluid in the pericardial cavity according to the TE-echocardiogram. Considering that the risk of fracture of the electrode implanted through the subclavian vein is high in the long term, it was decided to implant electrodes through the axillary vein [13]. The TightRail device was removed, and two more leads were placed through the previously placed axillary vein introducer into the right heart and inferior vena cava. The previous two guides have been removed. Next, two electrodes were implanted. Ventricular 5076 CapSureFix Novus 58 cm (Medtronic, USA) into the interventricular septum, atrial 5076 CapSureFix Novus 52 cm (Medtronic, USA) with satisfactory stimulation parameters. Further surgery with no features. The patient was discharged on the sixth day after surgery.

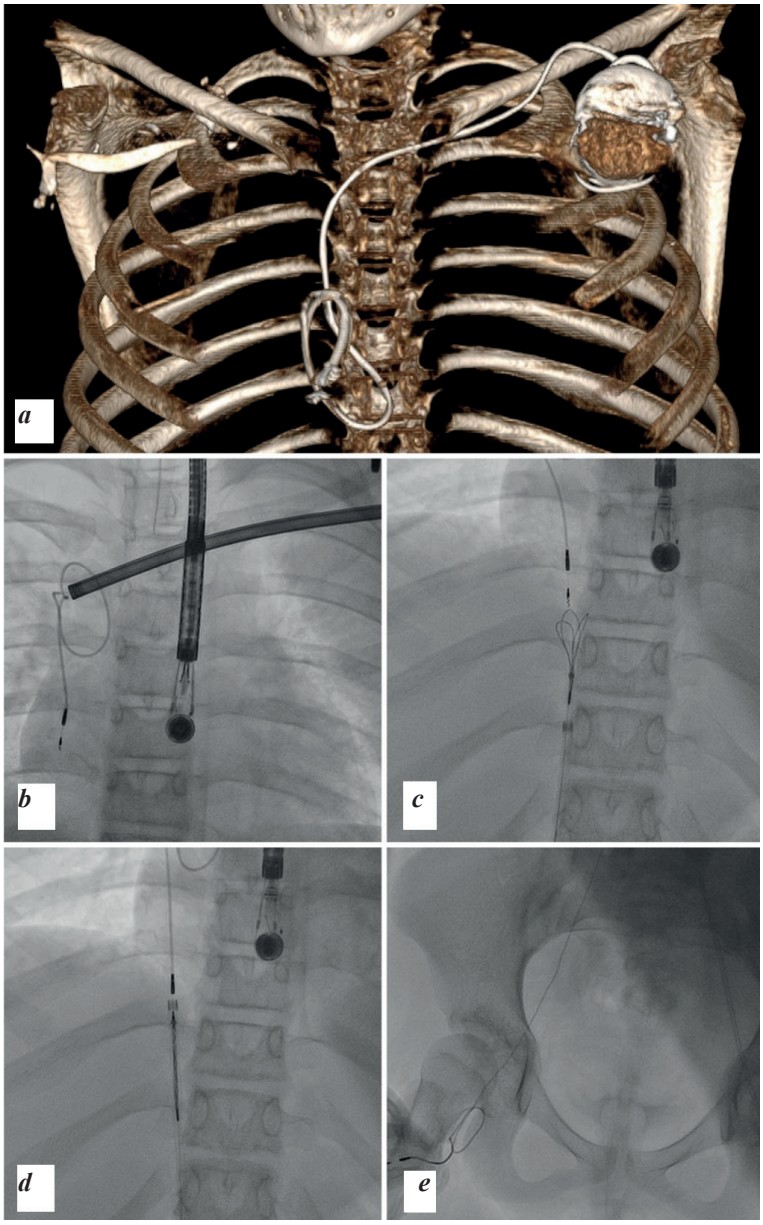

Fig. 2. Stages of treatment of an 11-year-old girl: a - multispiral computed tomography of the heart (the electrode is located in the right atrium, coiled with a loop), b - attempted TREE with TightRail 9Fr device, c-e - attempted TREE by femoral access with a three-loop trap.

Clinical Case 3

Girl, 6 years old, weight 21 kg, height 121 cm. The child underwent endocardial implantation of a dual-chamber pacemaker Adapta S (Medtronic, USA) for congenital complete AV blockade at the age of 2 years and 4 months. AE 5076 CapSureFix Novus 52 cm (Medtronic, USA) was implanted in the auricle of the right atrium. The 3830 SelectSecure VE (Medtronic, USA) was implanted in the interventricular septum. At 3 years 6 months after primary pacemaker implantation, an increase in the threshold of stimulation on VE and depletion of the pacemaker battery were detected. An attempt to implant a new electrode on the left failed, and occlusion of the left subclavian vein was detected. Single-chamber stimulation system implanted on the right, generator removed on the left. The old electrodes could not be removed by manual traction. The electrodes have been left in. Three months later, during a follow-up examination at the clinic, the girl's mother not-

ed that the child periodically complained of pain in the left subclavian region. Considering the risks of infectious complications and occlusion of the superior vena cava in the child in the long term, it was decided to remove the remaining electrodes.

Four years after the initial implantation of the device, transvenous extraction of the remaining electrodes was performed. Inhalation anesthesia. Invasive BP monitoring via the left radial artery. Surgery under the control of TE-echocardiogram. An infusion catheter and a 5 Fr intraducer were placed in the right femoral vein to provide transfemoral TREE in case of unsuccessful electrode removal through the subclavian vein. The postoperative scar was excised. The electrocoagulators isolated the remaining electrodes from the scar tissue up to the place of entry into the subclavian vein, the connector part of the electrodes was cut off. LLD EZ locking stylet (Spectranetics, USA) was inserted into the atrial electrode lumen, the electrode was removed by traction. The traction failed to remove the VE. TightRail 9 Fr device (Spectranetics, USA) was used for VE removal. Since the electrode to be removed was without an internal lumen, it was not possible to use a locking stylet. Two 0 silk ligatures were tied to the electrode, and the ligatures were passed through a rotary dilator. Hemodynamics remained stable. There is no fluid in the pericardial cavity according to TE-EchoCG. The patient was discharged on the fourth day after surgery.

Clinical case 4

Girl, 11 years old, weight 50 kg, height 130 cm. The complete form of AV canal was first identified at the age of 1 year. A related condition is Down syndrome. At one year of age, the girl underwent pulmonary artery narrowing, and at two years of age - radical correction of the malformation. The postoperative period was complicated by transient complete AV blockade, which required implantation of a single-chamber pacemaker (Adapta S ECS and 3830 SelectSecure electrode (Medtronic, USA)). The parents brought the child irregularly for follow-up examinations. Nine years after implantation a stimulation disorder was detected. The coiled loop electrode is located in the right atrial cavity (Fig. 2a). According to Holter monitoring - decreased HR up to 50 beats/min, pacemaker battery depletion. It was decided to remove the old electrode and implant a new stimulation system.

Inhalation anesthesia. Catheterization of the left femoral vein for infusion. Invasive blood pressure monitoring via the left femoral artery. Surgery under the control of TE-echocardiogram. A Prelude 5 Fr intraducer (Merit, USA) was placed in the right femoral vein to provide transfemoral TREE if necessary. Phlebography was performed through the left cubital vein: subclavian, brachiocephalic and superior vena cava veins were patent. The postoperative scar was excised. The electrodes are disconnected from the device. A puncture of the left axillary vein was performed. A 0.035» metal conductor is inserted into the inferior vena cava. The electrocoagulator electrode is isolated from the scar tissue to the site of entry into the subclavian vein. Given the electrode model, the use of a locking stiletto was not possible. The connector part of the electrode is cut off, and the electrode is lengthened with two silk ligatures. Attempted TREE with the TightRail 9 Fr device (Spectranetics, USA) (Fig. 2b). The electrode was isolated from the tight junctions in the subclavian and brachiocephalic veins by the device, but it was not possible to remove the electrode because it was not possible to straighten the loop in the atrium. It was decided to perform TREE by transfemoral access. The 5Fr introid was replaced by the long Avanty 6 Fr introid (Cordis, USA). The tip of the electrode is captured by an EnSnare three-loop trap (Merit, USA) and extended into the femoral vein (Figures 2c, 2d, 2e). However, it was not possible to retrieve the electrode because the size of the loop did not allow its removal through puncture access. The femoral vein was isolated, venotomy was performed, and the electrode was removed. The vein was sutured with Prolen 5/0 thread. Examination of the removed electrode revealed that the loops were tightly fixed between each other by calcinate (Figure 3). The patient had a new stimulation system implanted on the left side. The electrodes were implanted through the axillary vein. Postoperative period without complications.

DISCUSSION

When discussing cardiac pacing and its complications in children, guidelines for device implantation in pediatric practice should be followed. It is generally accepted that children weighing less than 15 kg are indicated for a single-chamber pacemaker and epicardial electrode implantation [14, 15]. However, recent guideline documents [1] do not clearly indicate who should be implanted epicardially and who should be implanted endocardially. In modern arrhythmology, it is not uncommon to find cases when children weighing less than 15 kg are implanted endocardially.

The presented clinical cases and literature analysis demonstrate the feasibility of epicardial electrode implantation in the group of patients under consideration, especially taking into account the possibilities of modern minimally invasive cardiac surgery [14-17]. Nevertheless, in real practice we have to face complications of endocardial stimulation in children more and more often. Survival of

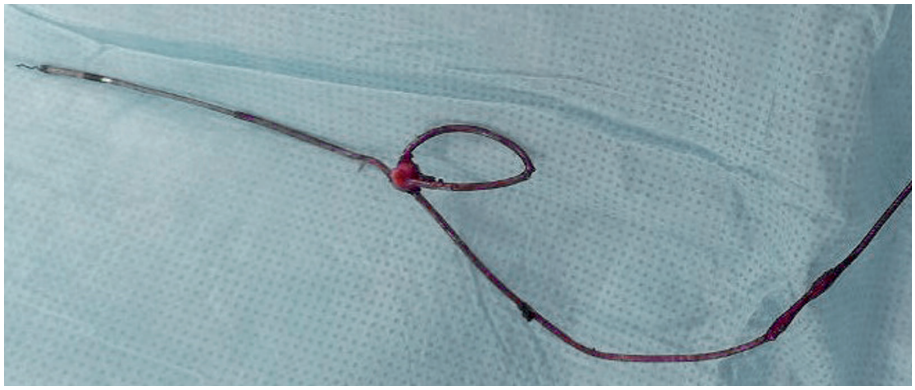

Fig. 3. Electrode removed from an 11-year-old girl (calcification is visible at the loop site).

electrodes implanted endocardially is lower in children than in adults [12]. This is primarily due to the continued growth and active lifestyles of patients. When implanting an electrode in a child, we always know that it will not function for life. At some point, a new electrode will have to be implanted, removing or leaving the old one in place.

Another major clinical problem in children is occlusions of the veins through which the electrodes are implanted. There are several prerequisites for this. The first is the large diameter of standard electrodes relative to subclavian/axillary veins, and the second is that in children the process of electrode encapsulation is more active and pronounced, up to calcinosis of the fibrous capsule.

When electrode function is impaired, two strategies are considered: remove the old electrode and implant a new one, or add a new electrode without removing the old one. Given the predicted life expectancy in these patients, the first approach is more rational, as the patient may «accumulate» 4-5-6 electrodes over a lifetime. Also, when addressing the problem of impaired stimulation in children, care should be taken not to compromise the contralateral side. Venous access on the contralateral side should be maintained as long as possible.

Despite the long history of cardiac pacing, there remains little experience with TREE in children. All studies support the data that TREE in children is more often performed for noninfectious indications due to electrode dysfunction and vein occlusion [7-12]. The Polish authors have the most published experience, having performed 63 TREEs in children [12]. In their paper, A.Kutarski et al (2022) noted that TREE in children was accompanied by great technical difficulties, and complete radiologic and procedural success was significantly lower than in adults. The authors attributed the difficulties of TREE in children to the formation of firm fibrous tissue around the electrodes. The capsule is often calcified.

Another feature of TREE in children and patients who had electrodes implanted in childhood is excessive loops in both atrium and ventricle [12]. We encountered a loop in the right atrium, with the electrode sites fixed to each other with calcium, and it was not possible to separate them with the rotational dilator. In our case, it was necessary to perform phlebotomy for electrode retrieval by femoral access. Because children develop early calcification of the fibrous capsule, it can be inferred that mechanical rotational dilators should be favored over laser in instrument selection [12].

TREE is associated with the risk of cardiac and large vessel damage [18]. Therefore, there is always the question of surgical support for these surgeries. Cardiac surgeons specializing in congenital heart disease surgery were always present at our surgeries, and the operating room had a ready-to-use artificial circulation machine and all the necessary instruments and consumables for open surgery.

As an alternative to TREE for venous occlusion, conduction recanalization in children may be difficult. We were unable to recanalize the child with vein guides either antegradely or retrogradely. Another problem with electrode removal in children is damage to functioning electrodes due to the fact that the dense fibrous capsule is uniform for all implanted electrodes. When rotary dilators are used, it is usually necessary to remove them and implant new ones [19].

In this category of patients, the question arises as to which electrodes should be preferably implanted endocardially in children when epicardial stimulation is not possible. In the early 2000s, the 3830 SelectSecure electrode (Medtronic, USA) with a diameter of 4.1 Fr was offered for implantation in children. The inner conductor of the electrode is made like a stranded cable, which provides high tensile strength [20]. The electrode is implanted using a guided or shaped introducer. The design of the electrode affects the specifics of its extraction - the use of locking styli is not possible. It is necessary either to use extension devices (Buldog, COOK, not registered in the Russian Federation) or to fix and extend the electrode with strong ligatures [21].

E.Shepherd et al showed that 9 of 22 (41%) 3830 electrodes could be removed with manual traction alone, compared with 2 of 35 (6%) conventional electrodes. All remaining electrodes were successfully removed using mechanical TREE tools [22]. J.Garnreiter et al (2015) also report a 6-year experience with the 3830 electrode in children with congenital heart disease. The mean follow-up time was 2 years, and 11 of 198 electrodes (6%) required removal. Seven electrodes were older than 1 year and five of them were older than 2 years. All electrodes were successfully removed by manual traction alone, with no complications [23]. We removed 5 electrodes of 3830 SelectSecure (Medtronic, USA). The electrodes were removed completely and without complications.

It is possible that in the future, the developed risk scales for TREE may help to make decisions about treatment tactics for non-infectious complications in children [24, 25] At low risks, the decision will be made to remove the electrodes; at high and very high risks, the tactic of adding new electrodes without removing the old ones may be considered. All of our patients had a low risk of TREE according to the EROS scale and an intermediate risk calculated by the SAFETY calculator.

CONCLUSION

Thus, electrode removal in children is a current and unresolved problem. The indication is more often electrode dysfunction combined with occlusion of the veins through which the electrodes are implanted. TREE in children is a more complex intervention than in adults. However, in the case of implantation of special thin electrodes, the risk of intervention is low. In children weighing less than 15 kg, minimally invasive epicardial electrode implantation is the method of choice.

REFERENCES

1. Shah MJ, Silka MJ, Silva JNA, et al. 2021 PACES Expert Consensus Statement on the Indications and Management of Cardiovascular Implantable Electronic Devices in Pediatric Patients. *Heart Rhythm*. 2021;18(11): 1888-1924. https://doi.org/10.1016/j.hrthm.2021.07.038.

2. Dambaev BN, Dzhaffarova OYu, Svintsova LI, et al.

A review of current approaches to pacing in children with atrioventricular blocks. *Siberian Journal of Clinical and Experimental Medicine*. 2020;35(3): 14-31 (In Russ.) https://doi.org/10.29001/2073-8552-2020-35-3-14-31.
3. Ergul Y, Yukcu B, Ozturk E, et al. Evalution of different lead types and implantation techniques in pediatric populations with permanent pacemakers: single-center with 10 years' experience. *Pacing and Clinical Electrophysiology*. 2021;44(1): 110-119. https://doi.org/10.1111/pace.14126.
4. Figa FH, McCrindle BW, Bigras JL, et al. Risk factors for venous obstruction in children with transvenous pacing leads. *Pacing and Clinical Electrophysiology*. 1997;20: 1902-1909. https://doi.org/10.1111/j.1540-8159.1997.tb03594.x.
5. Sanjeev S, Karpawich PP. Superior vena cava and innominate vein dimensions in growing children: An aid for interventional devices and transvenous leads. *Pediatric Cardiology.* 2006;27: 414-419. https://doi.org/10.1007/s00246-006-1133-6.
6. Bar-Cohen Y, Berul CI, Alexander ME, et al. Age, size, and lead factors alone do not predict venous obstruction in children and young adults with transvenous lead systems. *Journal of Cardiovascular Electrophysiology.* 2006;17: 754-759. https://doi.org/10.1111/j.1540-8167.2006.00489.x.
7. Cooper JM, Stephenson EA, Berul CI, et al. Implantable cardioverter defibrillator lead complications and laser extraction in children and young adults with congenital heart disease: Implications for implantation and management. *Journal of Cardiovascular Electrophysiology.* 2003;14: 344-349. https://doi.org/10.1046/j.1540-8167.2003.02500.x.
8. Moak JP, Freedenberg V, Ramwell C, et al. Effectiveness of excimer laser-assisted pacing and ICD lead extraction in children and young adults. *Pacing and Clinical Electrophysiology.* 2006;29: 461-466. https://doi.org/10.1111/j.1540-8159.2006.00376.x.
9. Dilber E, Karagöz T, Celiker A. Lead extraction in children and young adults using different techniques. *Medical Principles and Practice.* 2009;18: 356-359. https://doi.org/10.1159/000226287.
10. Cecchin F, Atallah J, Walsh EP, et al. Lead extraction in pediatric and congenital heart disease patients. *Circulation: Arrhythmia and Electrophysiology*. 2010;3: 437-444. https://doi.org/10.1161/CIRCEP.110.957324.
11. Zartner PA, Wiebe W, Toussaint-Goetz N, et al. Lead removal in young patients in view of lifelong pacing. *Europace.* 2010; 12: 714-718. https://doi.org/10.1093/europace/euq059.
12. Kutarski A, Miszczak-Knecht M, Brzezinska M, et al. Transvenous Lead Extraction in Pediatric Patients - Is It the Same Procedure in Children as in Adults? *Circulation Journal*. 2022 Dec 14 https://doi.org/10.1253/circj.CJ-22-0542.
13. Chan NY, Kwong NP, Cheong AP. Venous access and long-term pacemaker lead failure: comparing contrast-guided axillary vein puncture with subclavian puncture and cephalic cutdown. *Europace* 2017;19: 1193-7. https://doi.org/.1093/europace/euw147.
14. Dzhaffarova OYu, Svintsova LI, Plotnikova IV, et al. Permanent pacing in children: results of follow-up, assessment of complications. *Journal of Arrhythmology*. 2022;29(1): 32-38 (In Russ.) https://doi.org/10.35336/VA-2022-1-05.
15. Singh HR, Batra AS, Balaji S. Pacing in children. *Annals of Pediatric Cardiology*. 2013;6: 46-51. https://doi.org/10.4103/0974-2069.107234.
16. Termosesov S, Kulbachinskaya E, Polyakova E, et al. Video-assisted thoracoscopic pacemaker lead placement in children with atrioventricular block. *Annals of Pediatric Cardiology*. 2021 Jan-Mar;14(1): 67-71. https://doi.org/10.4103/apc.APC_93_20.
17. Costa R, Silva KRD, Martinelli Filho M, Carrillo R. Minimally Invasive Epicardial Pacemaker Implantation in Neonates with Congenital Heart Block. *Arquivos Brasileiros de Cardiologia*. 2017;109: 331-9. https://doi.org/10.5935/abc.20170126.
18. Pecha S, Burger H, Chung DU, et al. The GermAn Laser Lead Extraction RegistrY: GALLERY. *Europace*. 2022;0 (June): 1-9; https://doi.org/10.1093/europace/euac056.
19. McCanta AC, Tanel RE, Gralla J, et al. The fate of nontargeted endocardial leads during the extraction of one or more targeted leads in pediatrics and congenital heart disease. *Pacing and Clinical Electrophysiology*. 2014;37: 104-108. https://doi.org/10.1111/pace.12282.
20. Доступно по ссылке [Available from]: https://www.medtronic.com/us-en/healthcare-professionals/products/cardiac-rhythm/pacemakers/surescan-mri-pacing-leads/selectsecure-mri-surescan-model-3830.html].
21. Krainski F, Miller JP, Pretorius V, et al. What goes in may need to come out: Considerations in the extraction of a lumenless, fixed-screw permanent pacemaker lead. *Heart Rhythm* O2. 2020;1(2): 160-163. https://doi.org/10.1016/j.hroo.2020.04.007.
22. Shepherd E, Stuart G, Martin R, et al. Extraction of SelectSecure leads compared to conventional pacing leads in patients with congenital heart disease and congenital atrioventricular block. *Heart Rhythm*. 2015 Jun;12(6): 1227-32. https://doi.org/10.1016/j.hrthm.2015.03.004.
23. Garnreiter J, Whitaker P, Pilcher T, et al. Lumenless pacing leads: performance and extraction in pediatrics and congenital heart disease. *Pacing and Clinical Electrophysiology*. 2015 Jan;38(1): 42-7. https://doi.org/10.1111/pace.12508.
24. Sidhu BS, Ayis S, Gould J, et al. Risk stratification of patients undergoing transvenous lead extraction with the ELECTRa Registry Outcome Score (EROS): An ESC EHRA EORP European lead extraction ConTRolled ELECTRa registry analysis. *Europace.* 2021;23: 1462-1471. https://doi.org/10.1093/europace/euab037.
25. Jacheć W, Polewczyk A, Polewczyk M, et al. Transvenous lead extraction SAFeTY score for risk stratification and proper patient selection for removal procedures using mechanical tools. *Journal of Clinical Medicine*. 2020;9(2): 361. https://doi.org/10.3390/jcm902036.