Prevention and treatment of pericardial tamponade in the electrophysiology laboratory - an European Heart Rhythm Association Survey

Andreas Metzner MD[1], Arian Sultan MD[2], Piotr Futyma MD[3], Sergio Richter MD[4], Laura Perrotta MD[5], KR Julian Chun MD[6]

[1]University Heart and Vascular Center Hamburg/Germany;

[2]University Heart Center Cologne/Germany;

[3]St. Joseph`s Heart Rhythm Center Rzeszow and Medical College, University of Rzeszow/Poland;

[4]Heart Center Dresden, University Hospital, Technical University Dresden/Germany;

[5]Careggi University Hospital, Florence/Italy;

[6]CCB at Agaplesion Markus Hospital, Frankfurt/Germany

Adress for correspondence:

Andreas Metzner MD

University Heart and Vascular Center Hamburg-Eppendorf

Martinistr. 51

20246 Hamburg/Germany

Phone: ++49-40-7410 58320

Email: a.metzner@uke.de

Abstract:

Background

Pericardial tamponade (PT) is the most frequent severe complication during EP procedures and requires immediate, coordinated and effective treatment. However, multiple aspects of PT treatment are not standardized or under ongoing debate.

Methods

An online questionnaire consisting of 26 multiple-choice questions was sent out to the European Heart Rhythm (EHRA) Research Network and also distributed via social media outputs. The EHRA survey was conducted between May and June 2023.

Results

A total of 213 replies were received from European (87%), and non-European countries. 90% of all participants perform interventions in dedicated EP labs equipped with different ablation platforms. In case of PT most participants use X-ray as the main imagaing modality guiding pericardial puncture, predominantly aiming for an anterior puncture site. Sheaths of different sizes are introduced into the pericardial space (84.3%), followed by a pigtail catheter. Application of protamine is an established but variable step in the majority (84.6%). NOAC antidotes are not used by 73.3% of participants, while 15.2% routinely apply them. Retransfusion of aspirated blood is performed by 72.1% ((before protamin administration (18.2%), after protamin administration (13.5%), if pericaridal effusion cannot be controlled (40.4%)). 72.4% retransfuse without blood filter systems. The decision for surgical intervention is mostly taken if bleeding continues despite all interventional measures.

Conclusions

The current survey demonstrates that the management of PT is heterogeneous among centers. Findings of this survey may help to guide operators in their treatment and decisions in the setting of PT.

Introduction:

Catheter ablation is an established treatment option for various types of arrhythmias and in general has a high success rate and an excellent safety profile (1). However, despite increasing experience, improved ablation strategies and technologies complications can occur and can be potentially life threatening (2-14). Pericardial

tamponade (PT) is the most frequent severe complication during EP procedures and requires immediate, coordinated and effective treatment. However, the treatment of PT is not standardized and various aspects are debated (15). Therefore, we conducted a survey evaluating the infrastructure, safety precautions and treatment strategies in the setting of PT in European and non-European electrophysiology (EP) centers.

Methods:

An online questionnaire consisting of 26 multiple-choice questions was sent to the European Heart Rhythm (EHRA) Research Network and was also distributed via social media platforms. The exact questionnaire is provided as Supplementary Data. The EHRA survey was conducted between May and June 2023.

Results:

Baseline data

We received a total of 213 replies. The majority of respondends were from European (87%), and 13% from non-European countries (**Figure 1**). A total of 68% of all participants practice at academic institutions and 32% at non-academic hospitals. The number of ablation procedures per year varied from up to 500 EP-procedures in 45% of participants, 501-1000 procedures in 27%, 1001-1500 procedures in 14% and finally more than 1500 procedures in the remaining 15%. While 92% of all participating EPs report to perform diagnostic EP-procedures, 95% perform ablations of supraventricular tachycardias, 92% of atrial fibrillation, 94% of atrial flutter and 91% of ventricular tachycardia (VT). Of note, a total of 58% of responders perform epicardial VT ablation and 62% offer interventional occlusion of the left atrial appendage (**Figure 2**).

EP-infrastructure and equipment

Reflecting the spectrum and load of EP procedures, 90.2% of all participants perform their interventions in dedicated EP labs. With 91%, 3D-mapping in combination with irrigated contact force enabled radiofrequency (RF) catheters is the most frequently available ablation modality followed by a cryoballon technology (79.5%). Conventional RF ablation is applied in (71.4%), and non-contact force guided RF ablation with 3D mapping in

(44.6%). Of note, pulsed field ablation (PFA) is already widely spread and applied by 29.5% of all participants. Another 7.1% are also equipped with other ablation platforms.

About two thirds (65.8%) of all responders have institutional cardiac surgery on site. A total of 88.2% of the participants report to have echocardiography permanently available inside the EP-lab. Moreover, 94.6% answered to have a pre-prepared epicardial puncture set inside the lab which contains all items being necessary for emergency epicardial puncture and drainage.

Preprocedural considerations

While 72.7% participants report to have no restrictions for patient`s body mass index (BMI), 8.2% answered to have BMI limits for all procedures, and another 19.1% have BMI restrictions for left atrial and left ventricular ablation procedures only. BMI limits ranged between 35-55 kg/m^2. Regarding age, 85.2% have no age limits, while 3.7% have age limits for all procedures and 11.1% for left atrial and left ventricular interventions only (ranging from 75-85 years). INR limits for patients on vitamin K-antagonists were reported by 32.7%, with INR-limits ranging from 2-4. The remaining participants did not report INR restrictions for any EP procedures. 20.9% of responders do not interupt NOAC therapy, 15.5% stop it the day before, 18.2% the evening before, and 41.8% at the day of the procedure. 3.6% report other strategies.

Procedural aspects and safety considerations

1.8% of participants monitor blood pressure invasively during diagnostic EP-procedures, 9% during ablation of atrial flutter or atrial tachycardia, 13.6% during ablation of atrial fibrillation and 13.6% for interventional closure of the left atrial appendage. In VT ablation procedures, blood pressure is monitored invasively by 84.5%. Another 13.6% report to uniquely use non-invase blood pressure monitoring for all procedures.

Transseptal puncture is guided by fluoroscopy only in 48.9% of respondents. Transesopageal echocardiography (TOE) as an additional imaging mode is used by 27.5% and intracardiac echocardiography (ICE) by 24.8% of the participants. 48.9% purely rely on fluoroscopy and 6.4% report to use other guiding modalities for transseptal puncture (**Figure 3**). Diagnostic catheters are positioned within the coronary sinus by the majoritiy of participants (86.1%). 23.1% also place a diagnostic catheter at the His bundle region for transseptal puncture, and 8.3% use a

pigtail catheter or wire inside the aorta. The remaining 9.3% report to use no diagnostic catheter for guidance of transseptal punctures.

Additional modalities used for TSP are pressure control (50.1%), contrast staining of the fossa ovalis before advancing the transseptal needle (29.4%), introduction of a guidewire into the left atrium or the left superior pulmonary vein once transseptal puncture is performed (55.9%) and/or contrast injection after transseptal access (49%), respectively (**Figure 3**).

Treatment of pericardial tamponade

For pericardiocentesis of a PT most participants report to use X-ray as the main imgaing modality to guide pericardial puncture. The most frequently used views are anterior-posterior (AP, 58.7%) and left anterior oblique (45.2%). 14.2% also perform the puncture in a right anterior oblique angulation (14.4%). In addition to X-ray, echocardiography is used by 61.5%. A minority of responders does not use any imaging modality and 5.8% report to use other modalities. Pericardial puncture can be targeted on the anterior and the posterior site. An anterior access is preferred by most (67.3%). Once epicardial access is gained, most physicians (84.3%) introduce sheaths of different sizes into the pericardial space (5F 9.8%, 6F 35.3%, 7F 14.7%, 8F 21.6%, other sizes 2.9%), followed by a pigtail catheter (5F 23.5%, 6F 50%, 7F 19.6%, other sizes 6.7%).

The majority of respondents (84.6%) applies protamine in case of a PT. Timing of protamine injection varies with injection immediately upon diagnosis of PT in 42.7%, after complete drainage of PT in 35.4%, and after successful access to the pericardium in 17.7%. Some (4.2%) report other strategies regarding protamine application (**Figure 4**). The protamine dose is adjusted according tothe last measured ACT level in 43.3%, and 37.1% apply protaminin a 1:1 ratio to previous heparin administration. Among the remaining participants, 3000 I.E. and 5000 I.E. are given as an institutional standard in 4.1% and 9.3%, respectively.

NOAC antidotes are routinely administered by 15.2% of respondenst, while73.3% of them never use antidotes. Another 11.4% only apply NOAC antidotes in certain situations such as unresponsiveness of bleeding to protamine administration. Additional application of clotting factors is not considered by 91.7% of centers. However, 8.3% would apply prothrombin complex, fresh frozen plasma or tranexame acid as necessary.

Auto-transfusion of aspirated blood is reported to be done by 76% of all participants. Some start auto-transfusionbefore protamin administration (18.2%), others after protamin administration (13.5%), and others only

if pericaridal effusion cannot be controlled (40.4%). Another 1.9% report to have other strategies regarding re - or autotransfusion. For auto-transfusion, 72.4% of participants do not use a blood filter, 15.8% use a blood filter, and another 11.8% autotransfuse via a cell safer only (**Figure 5**). While 90.4% do not have a maximal limit of retransfused blood, 6.4% have defined limits (maximum of 1-2l), and 3.2% have different strategies.

The decision for surgical intervention is mostly taken if bleeding continues despite all interventional measures. Accordingly, 55.7% of the participants answered to decide for surgical backup and intervention if the bleeding continues for more than 60-80 min. Another 25.4% consider surgical assistance if the amount of aspirated blood exceeds a predefined limit, ranging from 1000 ml to 3000 ml among centers. Another 18.9% consider other measures such as no reduction of aspirated blood per minute, hemodynamic instability, or suspicision of a left atrial/ventricular defect.

Postinterventional aspects

After successful epicardial puncture, drainage and stabilization of the patient most respondents (48.5%) keep the pigtail catheter until there is no evidence of further bleeding after re-initiation of an indicated anticoagulation. Another 7.9% remove the pigtail as soon as the bleeding has stopped, and 43.6% report other strategies such as keeping the pigtail for two up to 72 hours, and including repeat echocardiography showing complete drainage of effusion without further aspiration.

Specific medications applied after PT drainage are nonsteroidal antiinflammatory drugs (NSAID) in 48.6% of participants for a mean of 10 days, colchicine in 47.2% for a mean of 19 days, cortisone in 8.3% as a single shot in the majority, and/or antibiotics in 31.9% for a mean of 2 days.

If indicated, anticoagulation therapy is re-initiated within 0-72 hours after pigtail removal.

Onsite cardiac surgery versus no onsite cardiac surgery

While many aspects between centers with and without onsite cardiac surgey are comparable, there are also major differences. The mean total number of procedures in participant`s centers with onsite cardiac surgery is higher with 850±595 versus 634±569. Operators at centers without cardic surgery less frequently report to perform epicardal

VT ablation (37% versus 72%) and protamine is more often regularly applied in case of percicardial tamponade (81% versus 70%).

Discussion:

Despite technological advancements and procedural expertise PT remains a frequent and potentially life-threatening complication in the EP-lab. However, in experienced centers and when managed by experienced operators PT can be effectively treated. There are no general recommendations on how to prevent and how to treat PT. The current survey found that:

1. Most centers have no restrictions regarding age and BMI even for complex left atrial/ventricular procedures.
2. Transseptal puncture is mostly performed fluoroscopically and frequently facilitated by diagnostic catheters and/or additional imaging modalities such as TOE or ICE.
3. In case of PT pericardial puncture is mainly guided by fluorosopy and echocardiography and most responders aim for an anterior puncture site, followed by introduction of a sheath and a pigtail catheter.
4. Protamine is applied by a majority of participants immediately when PT is diagnosed or after complete drainage of pericardial effusion. NOAC antidotes are only administered by a minority of respondents.
5. A majority does directly autotransfuse aspirated blood without a blood filter and with no maximal limit for blood retransfusion.
6. Surgical intervention is mainly considered if bleeding continues despite all interventional measures.

EP-infrastructure and equipment

While two thirds of all responders report to have institutional cardiac surgery, almost all state to have echocardiography permanently available inside the EP-lab and prepared epicardial puncture sets. Although institutional cardiac surgery might extent the window for interventional measures to treat PT, echocardiography permanently on hand and prepared puncture sets allow for straight forward and time-efficient diagnosis and emergency treatment without unnecessary loss of time.

Procedural aspects and safety considerations

Transseptal mispuncture is one of the main reasons for PT. Different techniques can be applied and finally the mode of transseptal puncture is influenced by individualized strategies and by personal experience. However, the ultimate demand is to perform transseptal punctures as controlled and as safe as possible. To facilitate transseptal puncture, many centers use catheters at different anatomical positions to improve understanding of the individual anatomy. A catheter inside the coronary sinus will provide a rough visualization of the mitral valve and left atrial dimensions. In addition, a synchronous movement of the transseptal sheath and transseptal needle assembly positioned at the fossa ovalis with the coronary sinus catheter indicates adequate septal contact and position. Some participants use an additional catheter at the His bundle region or a pigtail catheter or wire inside the aorta to mark the aortic root to prevent inadvertent aortic puncture (16,17). Mostly, transseptal puncture is guided by fluoroscopy only, but other imaging modalities might be added such as transesophageal or intracardiac echocardiography. Both echo modalities will not only help to guide the transseptal sheath and needle to the fossa ovalis but will also facilitate to specifically target anterior or posterior puncture sites within the fossa ovalis depending on the ablation system used (e.g. cryoballoon ablation posterior and inferior, in PFA ablation rather midseptal and inferior) or the intended ablation strategy (e.g. pulmonary vein isolation or antegrade left ventricular access). Transseptal puncture with pressure control is applied by most operators. Verification of successful left atrial access before advancing the transseptal sheath by either introducing a guidewire into the left atrium or a pulmonary vein or by injection of contrast medium avoids advancement of the sheath in case of inadvertent pericardial puncture.

Treatment of pericardial tamponade

There are different ways to get epicardial access but two thirds of all responders prefer an anterior epicardial puncture site which has been shown to be safer than a posterior one (18). In an analysis by Mathew et al. a posterior epicaridal access was strongly associated with a higher rate of severe puncture-related complications and a higher necessity for later surgical repair (18). Fluorscopy in different views and additonal echocardiography as answered by three out of four EPs are the leading imaging modalities to guide the puncture. Almost all participants introduce a sheath into the pericardial space as soon as access is established. A sheath has two major procedural advantages. First, it can be used for direct aspiration of blood and the bigger the size the more volume can be mobilized. Second, blood inside the pigtail catheter, which is introduced by a majority of participating EPs, can clot and in worst case the pigtail has to be exchanged. This is facilitated over the sheath as a continuous and safe access

to the pericardial space. Of note, in tall or obesed patients it might be beneficial to use a longer or even a transseptal sheath.

Hemostasis and anticoagulation play a major role in the acute treatment of PT. Protamine administration in order to antagonize previously applied heparin in left atrial/left ventricular procedures is an essential step. Especially in centers without institutional cardiac surgery backup, early application of protamine is the strategy of choice. However, the administration of protamine also bears a risk for clot formation inside the pericardial space which can complicate the situation by impeding further and complete drainage of the pericardial effusion. This is probaby the reason why about one third of responders decide to first aspirate all blood from the pericardium before protamine is administered. In about 80% the dose of protamine depends on previously measured ACT levels or of the total dose of applied heparin.

Additional application of clotting factors or DOAC antidotes is not performed by the majority of responders. While clotting factors such as PPSB, prothrombin complex or fresh frozen plasma are only considered by 8.3%, NOAC antidotes are routinely applied by only 15.2%. The decision to administer NOAC antidotes might be influenced by costs but also by the fact that PT even in patients under NOAC therapy might be safely and effectively managed without antidotes.

Autotransfusion of aspirated blood is an important but disputatious aspect in PT management. Potential advantages are immediate use, easy implementation, low costs, avoidance of volume and blood loss and thus mostly no need for donor blood transfusion. Accordingly, 74% of all participants perform retransfusion of aspirated blood and almost three thirds do it directly and without a mechanical blood filter. About 16% use a blood filter and 12% would retransfuse via a cell safer. However, the use of latter is time-consuming to prepare and therefore often not practicable in the emergency situation. Of note, 90% report to not have a fixed volume limit and would retransfuse aspirated blood as long as neccessary and reasonable.

Involvement of surgical backup and repair is also a controversial point. Centers having an institutional cardiac surgery may have more leeway since the decision for surgical repair can be taken anytime if the patient`s condition demands. However, if there is no institutional cardiac surgery but rather external cardiac surgical cooperation partners, the decision for potential surgical repair mightl be taken at earlier stages of the treatment cascade. The important aspect is to have cardiac surgical backup which is permanently available or on demand. The point in time to decide for surgical intervention is certainly very individual. In our survey 56% stated to involve surgeons if the bleeding continues for more than 60-80 min, while another 25% would do if the total amount of aspirated blood would exceed an amount of up to 3000 ml.

Postinterventional aspects

Keeping the pigtail catheter in place for several hours after successful treatment of PT is double edged (19). First, further drainage from the pericardium might be neccessary in case of ongoing or recurring bleeding. At the other hand, pericarditis might develop if the pigtial catheter is kept and patients normally complain about thoracic discomfort. In the survey almost 50% of respondents state to keep the pigtail catheter until there is no evidence of further bleeding after re-initiation of an indicated anticoagulation. There are different types of medical strategies following pericardial puncture and drainage aiming mainly for pain relief and prevention of pericarditis including NSAIDs and colchicine applied by almost 50% of responders each. Also antibiotics are applied by more than 30% of responders, but mostly for only 2 days.

The decision for reinitiation of an indicated oral anticoagulation after pigtail removal has to be carefully taken. At one hand, left atrial thrombus formation and potential ischemic stroke needs to be prevented, at the other hand there would be the risk of ongoing or recurrent bleeding. With 0-72 hours, there is a broad window within which anticoagulation is reinitiated by respondents.

Onsite cardiac surgery versus no onsite cardiac surgery

Having onsite cardiac surgery may not only affect the spectrum of EP procedures that is performed but also the mode of treatment in case of a PT. While many parameters of our analysis given by the participants are comparable, there are also differences: in centers with onsite cardiac surgery the mean no. of performed procedures is higher. Although epicardial VT ablation is frequently offered at centers with onsite cardiac surgery, the number of participants reporting on epicardal VT ablation without having onsite cardiac surgery is considerably high with 37%. This finding is of interest when considering the ongoing debate on whether a procedure with a rather high incidence of major complications such as severe PT should be offered and performed at such centers. Moreover, protamine is less often applied by participants at onsite cardiac surgery centers. In centers without cardiac surgery usually all efforts are taken to stop the bleeding as soon as possible and thus protamine might be applied at earlier stages of the treatment cascade.

Limitations:

Analyzed data is based on per physician and not per center level, thus overestimating large EP centers perspectives cannot be ruled out. The voluntary nature of the survey favors selection bias, and raises questions whether these results represent a realistic reflection of the current practice. The survey included a limited number of 26 questions only. Therefore, further details such as incidences of PT or the need for surgical intervention cannot be provided.

Conclusions:

The current survey demonstrates that the management of cardiac tamponade differs between EP-centers. Findings of this survey may help to guide operators in their treatment and decision in the setting of PT.

Acknowledgements:

The production of this document is under the responsibility of the Scientific Initiatives Committee of the European Heart Rhythm Association:

Julian K.R. Chun (Chair), Sergio Castrejon (Co-Chair), Ante Anic, Giulio Conte, Piotr Futyma, Andreas Metzner, Federico Migliore, Giacomo Mugnai, Laura Perrotta, Rui Providencia, Sergio Richter, Laurent Roten, Arian Sultan

The authors acknowledge the EHRA Scientific Research Network centres participating in this survey. A list of these centres can be found on the EHRA website.

Funding/Financial Disclosure:

No funding. None of the authors states any financial disclosures relevant for the submitted work.

Figures:

Data availability statement:

All relevant data are within the manuscript and its Supporting Information files.

References:

1. Hindricks G, Potpara T, Dagres N, Arbelo E, Bax JJ, Blomström-Lundqvist C et al.; ESC Scientific Document Group. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. Eur Heart J. 2021 Feb 1;42(5):373-498. doi: 10.1093/eurheartj/ehaa612. Erratum in: Eur Heart J. 2021 Feb 1;42(5):507. Erratum in: Eur Heart J. 2021 Feb 1;42(5):546-547.

2. Cappato R, Calkins H, Chen SA, Davies W, Iesaka Y, Kalman J et al.. Updated worldwide survey on the methods, efficacy, and safety of catheter ablation for human atrial fibrillation. Circ Arrhythm Electrophysiol. 2010 Feb;3(1):32-8.

3. Deshmukh A, Patel NJ, Pant S, Shah N, Chothani A, Mehta K et al.. In-hospital complications associated with catheter ablation of atrial fibrillation in the United States between 2000 and 2010: analysis of 93 801 procedures. Circulation. 2013 Nov 5;128(19):2104-12.

4. Cheng EP, Liu CF, Yeo I, Markowitz SM, Thomas G, Ip JE et al.. Risk of Mortality Following Catheter Ablation of Atrial Fibrillation. J Am Coll Cardiol. 2019 Nov 5;74(18):2254-2264.

5. Fink T, Sciacca V, Feickert S, Metzner A, Lin T, Schlüter M et al.. Outcome of cardiac tamponades in interventional electrophysiology. Europace. 2020 Aug 1;22(8):1240-1251.

6. Bollmann A, Ueberham L, Schuler E, Wiedemann M, Reithmann C, Sause A et al. Cardiac tamponade in catheter ablation of atrial fibrillation: German-wide analysis of 21 141 procedures in the Helios atrial fibrillation ablation registry (SAFER). Europace. 2018 Dec 1;20(12):1944-1951.

7. Chierchia GB, Capulzini L, Droogmans S, Sorgente A, Sarkozy A, Müller-Burri A et al. Pericardial effusion in atrial fibrillation ablation: a comparison between cryoballoon and radiofrequency pulmonary vein isolation. Europace. 2010 Mar;12(3):337-41.

8. Yang E, Ipek EG, Balouch M, Mints Y, Chrispin J, Marine JE et al. Factors impacting complication rates for catheter ablation of atrial fibrillation from 2003 to 2015. Europace. 2017 Feb 1;19(2):241-249.

9. Doldi F, Geßler N, Anwar O, Kahle AK, Scherschel K, Rath B et al. In-hospital mortality and major complications related to radiofrequency catheter ablations of over 10 000 supraventricular arrhythmias from 2005 to 2020: individualized case analysis of multicentric administrative data. Europace. 2023 Feb 8;25(1):130-136.

10. Ekanem E, Reddy VY, Schmidt B, Reichlin T, Neven K, Metzner A et al; MANIFEST-PF Cooperative. Multi-national survey on the methods, efficacy, and safety on the post-approval clinical use of pulsed field ablation (MANIFEST-PF). Europace. 2022 Sep 1;24(8):1256-1266.

11. Schmidt B, Bordignon S, Neven K, Reichlin T, Blaauw Y, Hansen J et al. EUropean real-world outcomes with Pulsed field ablatiOn in patients with symptomatic atRIAl fibrillation: lessons from the multi-centre EU-PORIA registry. Europace. 2023 Jul 4;25(7):euad185.

12. Eckardt L, Doldi F, Anwar O, Gessler N, Scherschel K, Kahle AK et al. Major In- Hospital Complications after Catheter Ablation of Cardiac Arrhythmias - Individual Case Analysis of 43,031 Procedures. Europace. 2023 Dec 15:euad361. doi: 10.1093/europace/euad361. Epub ahead of print.

13. Darden D, Aldaas O, Du C, Munir MB, Feld GK, Pothineni NVK et al. In-hospital complications associated with pulmonary vein isolation with adjunctive lesions: the NCDR AFib Ablation Registry. Europace. 2023 May 15;25(5):euad124.

14. Darma A, Dinov B, Bertagnolli L, Torri F, Lurz JA, Dagres N et al. Cardiac tamponade complicating ventricular arrhythmia ablation: Real life data on incidence, management, and outcome. J Cardiovasc Electrophysiol. 2023 Feb;34(2):403-411.

15. Metzner A, Reubold SD, Schönhofer S, Reißmann B, Ouyang F, Rottner L et al. Management of pericardial tamponade in the electrophysiology laboratory: results from a national survey. Clin Res Cardiol. 2022 Jun 17. doi: 10.1007/s00392-022-02042-x. Epub ahead of print. Erratum in: Clin Res Cardiol. 2023 Jun;112(6):854.

16. Wasmer K, Zellerhoff S, Köbe J, Mönnig G, Pott C, Dechering DG et al. Incidence and management of inadvertent puncture and sheath placement in the aorta during attempted transseptal puncture. Europace. 2017 Mar 1;19(3):447-457.

17. Chen H, Fink T, Zhan X, Chen M, Eckardt L, Long D et al. Inadvertent transseptal puncture into the aortic root: the narrow edge between luck and catastrophe in interventional cardiology. Europace. 2019 Jul 1;21(7):1106-1115.

18. Mathew S, Feickert S, Fink T, Rillig A, Reissmann B, Rottner L et al. Epicardial access for VT ablation: analysis of two different puncture techniques, incidence of adhesions and complication management. Clin Res Cardiol. 2021 Jun;110(6):810-821.

19. Zhao Q, Li L, Liu N, Zhang M, Wu K, Ruan Y et al.. Early versus delayed removal of the pericardial drain in patients with cardiac tamponade complicating radiofrequency ablation of atrial fibrillation. J Cardiovasc Electrophysiol. 2020 Mar;31(3):597-603.

Figures:

Figure 1:

Participating countries

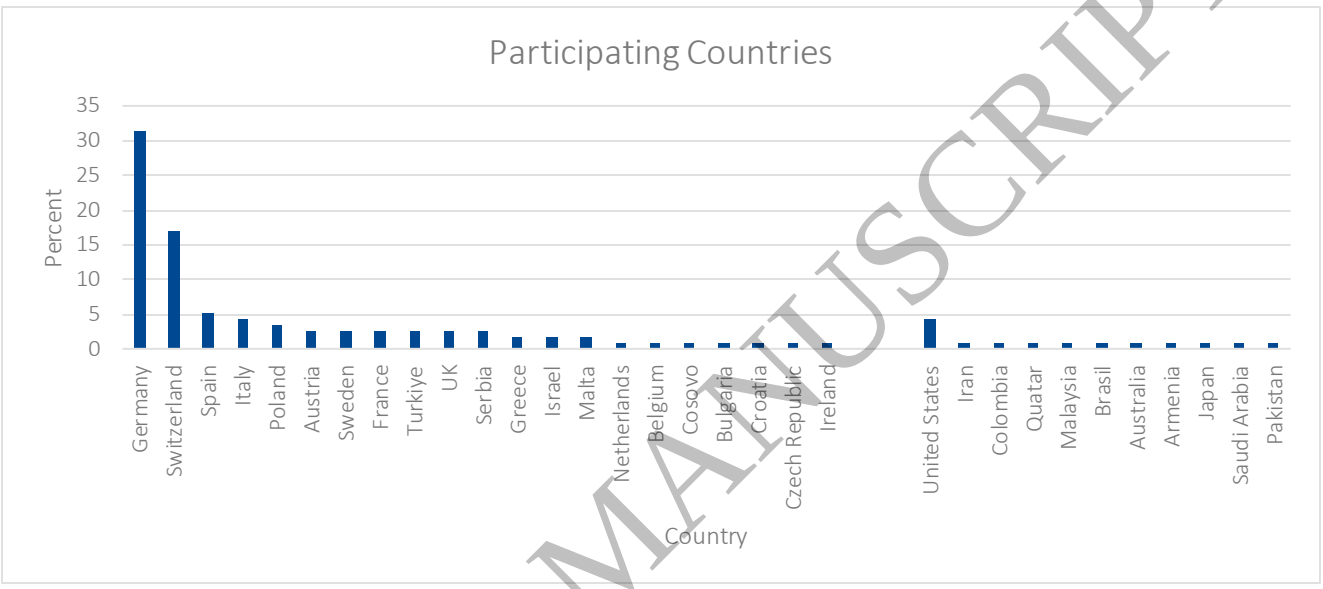


Figure 2:

Spectrum of procedures

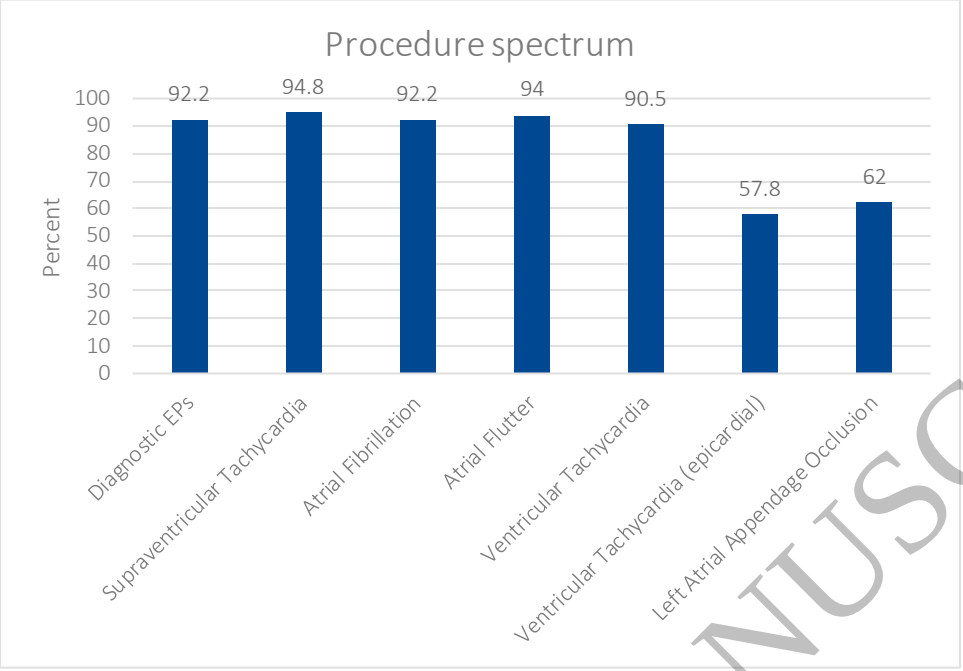
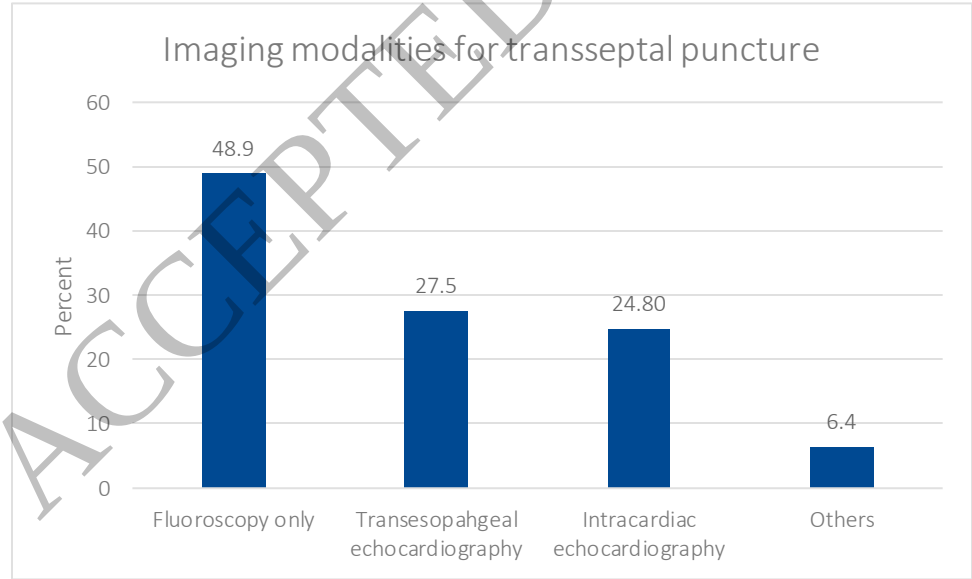


Figure 3:



Imaging modalities for transseptal puncture

Figure 4:

Application of protamine

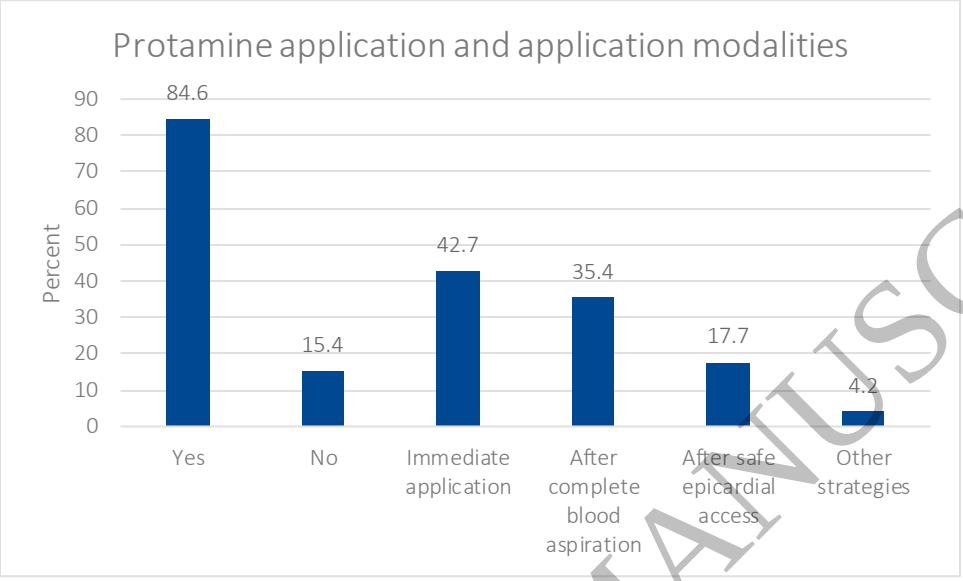
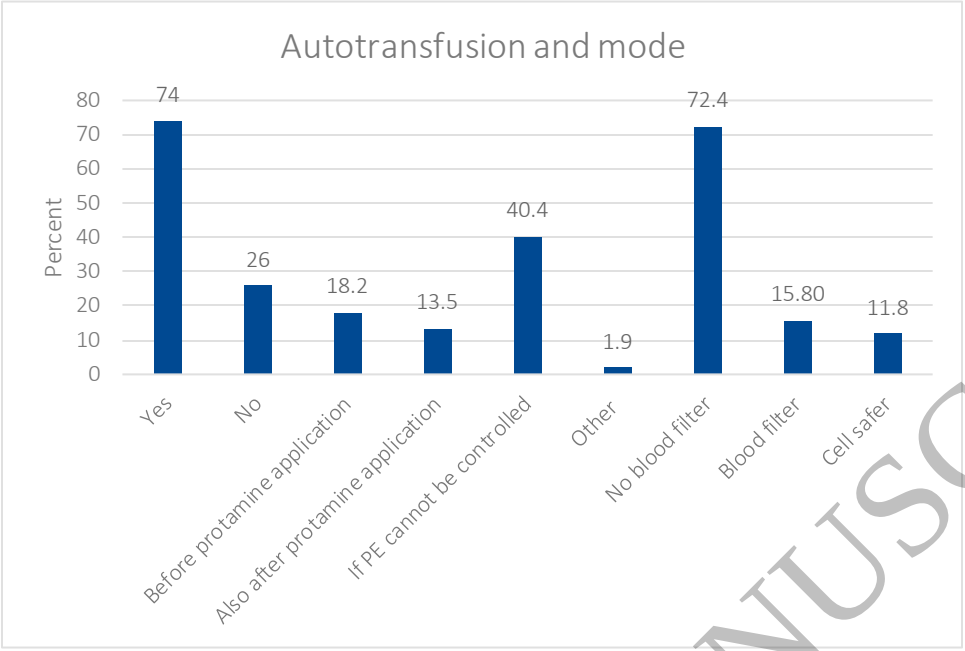


Figure 5:

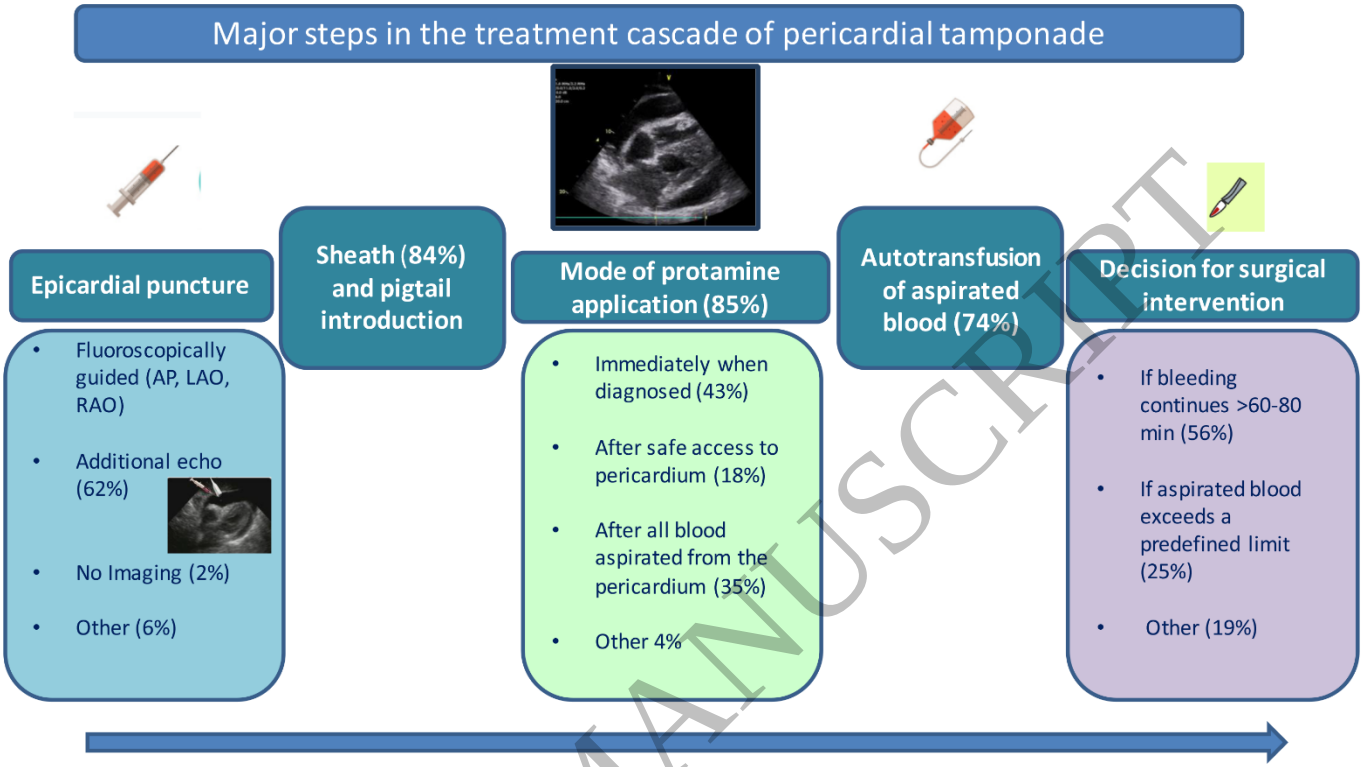
Autotransfusion of aspirated blood and mode of autrotransfusion



1

2

3



Graphical Abstract
254x143 mm (x DPI)