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Catheter ablation in the treatment of electrical storm: Integrative review

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Background: The incidence of electrical storm (ES) has been increasing with the rise of the indicated uses of implantable cardioverter defibrillators (ICDs). It is estimated that 20% of patients will evolve to have this complication. Ablative therapy stands out as the treatment for this condition when it is refractory to antiarrhythmic treatment. The objective was to define the current role of catheter ablation in the treatment of electrical storm.

Methods: An integrative literature review was performed using the PubMed and BVS databases. All identified articles were screened and verified for eligibility by the authors.

Results: Twenty-five out of the initial 951 articles were used in the final analysis. The categories listed for analysis included indication for ablation in ES, modality of the approach, therapeutic success, complications related to the procedure, mortality and cardiovascular follow-up and alternative therapeutic modalities by frequency of these categories in the articles researched.

Conclusion: Catheter ablation is the initial therapy for patients with ischemic cardiomyopathy (ICM) and ES. The endocardial approach presents more relevant success rates than the other therapeutic methods presented.

1. Introduction

According to some authors, electrical storm (ES) can be defined as the occurrence of three or more episodes of ventricular tachycardia (VT) separated by 5 min during one day or the presence of incessant VT despite the optimization of antiarrhythmic drug therapy. Its incidence has been increasing gradually, mainly in relation to the increased indications for the use of implantable cardioverter defibrillators (ICD) as non-pharmacological therapy for severe ventricular arrhythmias and prevention of sudden cardiac death [1–7].

Currently, it is estimated that 20% of patients with an ICD will evolve to such a condition that translates to a medical emergency in clinical practice [3]. However, when we only analyze the incidence of ES in patients with ischemic cardiomyopathy (ICM) and ICD, these numbers can reach 40% if the device is indicated for the prevention of secondary sudden death [8].

It is believed that the main triggering mechanism in acute ischemic heart disease is premature ventricular contractions (PVCs) that end up perpetuating the focus of reentry. However, this same explanation does not seem to correspond to the mechanism of ES in chronic ischemic heart disease or in addition to other cardiopathies that may hinder the understanding and treatment of this condition [9].

Epidemiological studies have shown that the occurrence of ES in patients with structural heart disease is associated with increases in their morbidity and mortality and that 50% of patients will progress to death within two years. These data demonstrate that the presence of ES is an important predictor of mortality in these patients, with a significant worsening in their quality of life [10].

Currently, ablative therapy stands out as the initial treatment for patients with ischemic heart disease who develop this condition refractory to antiarrhythmic treatment, as it is an effective and safe method to be performed in these patients [8]. Recent literature reviews consider catheter ablation to be promising in ES, but it still is not defined as the definitive treatment for this condition [4,5,7].

Based on the increasing number of ICDs in use currently [11], the high rates of patients who develop ES, the emergence of new techniques for the treatment of ES and current treatment using

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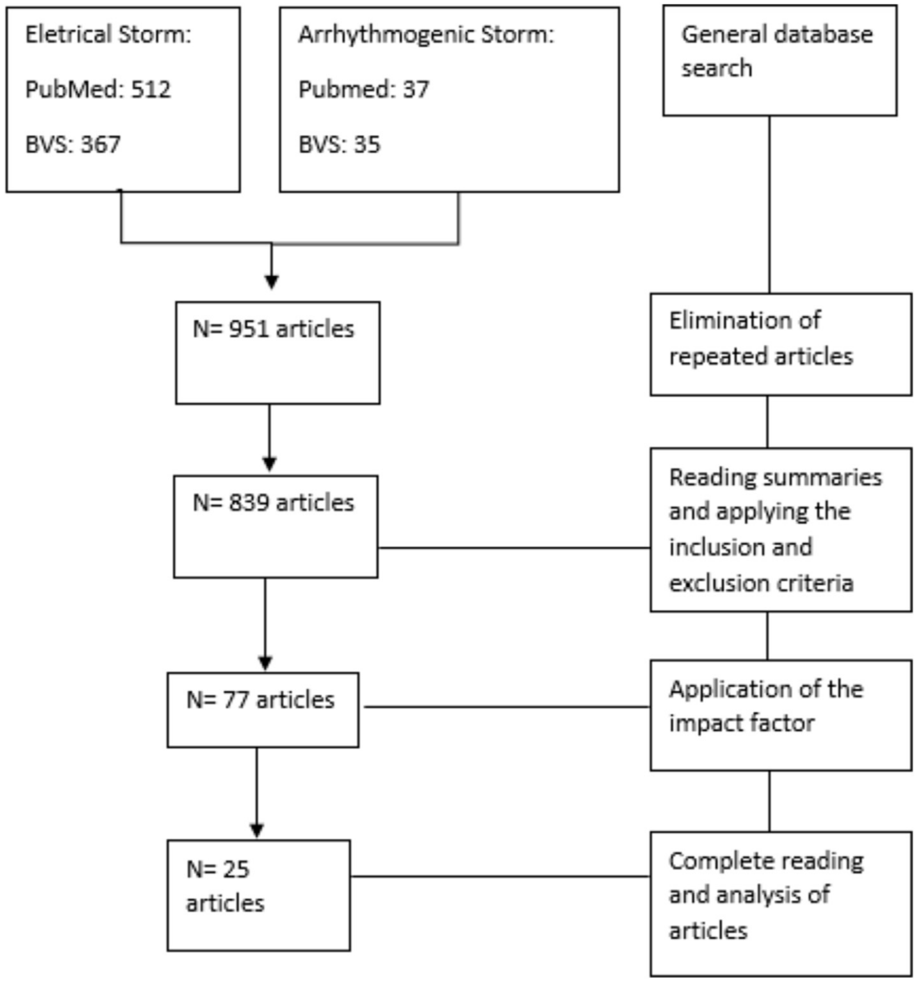

Fig. 1. Flowchart of literature search in PubMed/BVS and selection of articles.

ablative therapy, we proposed a study with the main objective of defining the current role of catheter ablation in the treatment of ES.

2. Methods

The research followed the standard [12,13] for performing an integrative review using the PubMed and BVS databases. Key words were used in both databases in order to evaluate all of the articles related to the subject, i.e., electrical storm, arrhythmogenic storm and their correspondents in Portuguese. The survey was supplemented by manual analysis of the list of articles.

The inclusion of articles resulted from a four-step process that consisted of initial bibliographic research, screening of the literature resulting from the research (through the reading of abstracts), evaluation of the eligibility of the articles provided by the screening and complete reading of the articles for final selection. In this sampling, only English and Portuguese languages were included.

We considered articles that were published beginning in 2010, and the last access for verification of new articles on the site was made on 09/20/16. All articles reporting ES were considered eligible, thus establishing a single inclusion criterion. Initially, the abstracts and titles were selected and read, and then the following exclusion criteria were applied: articles that only mentioned ES, articles that did not address ablation, and articles that were published in journals whose impact factor (IF) was lower than 1.

This impact factor has been chosen because we have observed that the publications were approaching the issue from similar analyzes. By using this exclusion criterion to arrange an analysis in this study, those items have gone through more rigorous review filters before publication, thus regarding their content.

3. Results

We found 951 abstracts of articles published in the period of analysis with the aforementioned key words, 549 in the PubMed database and 402 in the BVS database. After exclusion of the repeated articles, 839 articles remained, and their abstracts were read. In these, the inclusion and exclusion criteria were applied, leaving 25 articles as the final number of articles to be analyzed in this study (see Fig. 1).

The categories listed for analysis included indication of ablation in ES, modality of the approach, therapeutic success, complications related to the procedure, mortality and cardiovascular follow-up, and alternative therapeutic modalities. These categories of analysis were selected by the frequency of themes in the articles that were surveyed and based on previous reviews by Chan et al. (9), Yamada et al. (14) and Tsuji et al. [15] on the subject; these reviews addressed the issue in a similar way.

3.1. Indication of endocardial and epicardial ablation in ES

Most studies selected for this review agree with the definition of ES as the occurrence of three or more VT/VF episodes separated by more than 5 min during 24 h that triggered appropriate ICD intervention [8,16]. They indicate endocardial ablation after a failed attempt with antiarrhythmic drug treatment. Pluta et al. [17] described recurrence of ES as a result of instability and pharmacotherapy resistance while performing radiofrequency ablation in 21 patients with ischemic heart disease.

Endocardial radiofrequency ablation is also indicated as rescue therapy (10), since antiarrhythmic therapy with amiodarone and sympathetic blockade may leave some patients electrically unstable or require a longer time to stabilize, especially with amiodarone; they can also evolve to have arrhythmia recurrence after the procedure. Thus, in cases of ES occurring after acute myocardial infarction, endocardial ablation of ventricular extra systoles becomes an alternative [18].

3.2. Modality of approach

Ablation can be both endocardial and epicardial depending on the location of the arrhythmic substrate, which varies according to the type of underlying disease of the patient. Patients with non-ischemic cardiomyopathy usually require an epicardial approach because the arrhythmogenic substrate is often located at this site, whereas those with ICM are submitted to an endocardial approach for the same reason [4,14].

Bella et al. [19] collected data from 218 patients who were submitted to epicardial ablation. The approach was performed primarily in 35.8% of the procedures and secondarily, after failure of the previous endocardial ablation, in 64% of the procedures, indicating that ablation is also performed secondarily, as a rescue therapy.

The endocardial approach would be indicated mainly in heart diseases with endocardial scarring [14]. These scar locations are the typical location of the reentrant circuit common to all ventricular tachycardia related to healing of a previous infarction. Endocardial ablation aims to eliminate this circuit. Nedios et al. (20) indicates that in these cases, the electro-anatomical mapping needs to be obtained prior to the procedure and Conti et al. [4] emphasizes its importance in guiding ablation. In the report by Report et al. [1], the endocardial approach was successfully used to treat patients with ischemic heart disease; similarly, Pluta et al. [17] treated 21 patients and Kautzner et al. [21] treated 9 with this approach, corroborating the role of this approach in the reentry mechanisms cited by Yamada et al. [14].

The role of electro-anatomical mapping has been well established at the present time. All articles describing endocardial ablation cite its achievement, some studies in a direct way as in Bänsch et al. [18], Conti et al. [4], Lemery et al. [22] and Press et al. [23], while others describe how the procedure is performed, as in Yamada et al. [14], Pluta et al. [17], Bella et al. [19], Nedios et al. [20] and Roque et al. [24].

Among the approaches to access the left ventricle (LV), the transaortic and transseptal pathways stand out. In the study by Pluta et al. [17], the endocardial surface of the LV was similarly accessible in both methods, but when using the transseptal approach, a less detailed mapping of the interventricular septum was established and recorded. The success rate of ablation was similar in both groups (transseptal 83% vs. transaortic 80%); however, there is a preference for the transseptal pathway. Jin et al. [25] performed the transseptal approach in 40 patients and Arya et al. [6,16] in 43. In contrast, Kozeluhova et al. [8] used the transaortic approach to access the left ventricle and perform ablation in 50 patients.

3.3. Therapeutic success

Most studies agree on the definitions of success and failure of ablation; success may be absolute or partial. Absolute success can be defined as the absence of induction of any VT (clinical or not) at the end of the procedure (tested by programmed pacing protocol), and partial success can be defined as the absence of clinical VT. Failure is defined as the induction of clinical VT at the end of the procedure [6,16,25].

For patients with stable VT, activation and entrainment mapping during VT is important for identification of the critical circuit. Although this is ideal, clinical VT in the majority of patients is either noninducible or hemodynamically unstable, and multiple VTs are often induced, rendering conventional mapping techniques ineffective. To a certain extent, substrate mapping combined with pace mapping techniques during sinus rhythm have overcome these limitations [36,37].

Arya et al. [16] observed that of 30 patients treated with ablation, 24 had complete success and 6 partial success, with no failures. Murata et al. [26] described complete success in 100% (n = 9) of patients who were refractory to drug therapy. Kautzner et al. [21] published his experience with ablation in VF in ischemic heart diseases, reporting nine patients; ablation was successful in 8 patients (88%). VT ablation was performed in 12 patients by Roque et al. [24], and failure to induce any VT (complete acute success) was achieved in 8 patients (67%), whereas clinical tachycardia alone was achieved in 4 (33%). Jin et al. [25] analyzed ablation in 40 patients with complete success in 32 (80%), partial success in 6 (15%) and failure in 2 (5%). Deneke et al. [10] reported the procedure in 32 patients with complete success rates in 19 (62%), partial success of 32% and failure of 6%, and if we consider only patients with ICM, the complete success rate increased to 65%, partial success to 24% and failure to 11%. Kozeluhova et al. [8] described complete success in 44% of patients and partial success in 40% of their sample (n = 50).

According to the review by Nayyar et al. [7], the ablation of ES has high success rates with low rates of recurrent storms. The initial success rate was 72%, and the failure rate in the procedure was 9% (n = 471). Only 6% of the patients had a recurrence of ES.

The average success among the articles that were found is influenced by the type of heart disease that the author addresses. In the largest studies that analyzed ES in patients with ICM, we have a complete success rate between 60 and 80%, a partial success rate between 15 and 25% and a failure rate of 0–10%.

3.4. Complications related to the procedure

Most articles that analyze this topic choose to divide complications into major and minor depending on the severity of the complication. According to Peichl et al. [27], major complications are those that lead to long-term disability, requiring hospitalization or increased hospitalization time. Among the articles that were evaluated, there is no consensus on the role of minor complications, Jin et al. [25] chose to define minor complications, such as pericarditis and inguinal bruising in the puncture site. Peichl et al. [23], Bella et al. [19] and Deneke et al. [10] also included in this question transient Total Atrioventricular Block (BAVT), Left Bundle Branch Block (LBBB) and transient acute heart failure.

Peichl et al. [27] described the main complications related to ablation that was performed in 548 of their patients. It has been reported that complications occur in 6.2% of the sample; complications were more frequent in patients with previous structural damage and can reach indexes of 15%. In this study, of the 44 patients who had major complications, the following was observed: three patients with cardiac tamponade; five with thromboembolic events, two with cerebrovascular accidents (AVCs), one with transient ischemic attack (AIT), one with peripheral embolization of cholesterol and one with ischemic attack five days after the procedure; seven patients had infarctions in the conduction system evolving to infra-Hisian bradycardia and requiring a pacemaker, one with a trifascicular block, and one with a left bundle branch block resulting in exacerbation of heart failure. The authors further argue that although it is not the most common complication, the most feared one should be cardiac tamponade as a result of the imminent risk of life and proposal of complication predictors, including advanced age, reduced FE, previous structural damage, increased creatinine, and procedures realized as a result of the urgency of ES.

These data are corroborated by other authors such as Bella et al. [19] and Deneke et al. [10] with similar complication rates (4.1% and 3%, respectively). Among the major complications, the most important is cardiac tamponade. Minor complications are usually related to complaints at puncture sites, but others such as transient acute heart failure, transient BAV block and permanent LBBB situations have also been described. In addition to these data, Deneke et al. [10] observed a death during the procedure by electromechanical dissociation in a patient with ICM and an FE of 12%.

In contrast, Jin et al. [25] do not report any complications such as cardiac tamponade, thromboembolic events or important bleeding.

3.5. Mortality and cardiovascular follow-up

According to Deneke et al. [10], Peich et al. [27] and Jin et al. [25], both the presence of ES and the recurrence of arrhythmia less than 30 days after ablation are predictors of mortality in patients with ICM and ICD. In this context, new studies are needed to evaluate the cardiovascular outcome of patients undergoing ablation, with serial follow-up and cardiac evaluation to better characterize the benefits and harms of this treatment. Kozeluhova et al. (8) indicates other possible predictors of adverse outcomes such as: severely depressed FE, LV dilation and DRC; however, Peichl et al. [27] did not report chronic renal failure (CRF) or reduced ejection fraction (EF) as predictors of mortality.

Jin et al. [25] presented a series of cases with a follow-up of 17.4 (+- 16.9) months; of the 40 patients, 19 (47.5%) had no sustained VT recurrence and received no ICD therapy. A total of 10 patients (25%) who died after ablation were reported, one patient as a result of cardiogenic shock and severe IC, 7 as a result of IC evolution, with an average EF of 20% (±7.5%); the other 2 died of ischemic stroke and hemorrhagic stroke. Similar data were presented by Kozeluhova et al. [8], demonstrating that 48% of patients were free of recurrence of VT during a follow-up of 18 months (+−16 months); in Kautzner et al. [21], we observed an index of 55% of patients without arrhythmia recurrence.

However, during a 15-month follow-up, Deneke et al. [10] demonstrated that 69% of patients did not present recurrence of VT or any ICD therapy, in agreement with Arya et al. [16], demonstrating that 70% of the analyzed patients remained free of recurrence or antiarrhythmic therapy from the ICD. This last study also demonstrated that the maintenance of therapeutic success was greater in the group of patients who had complete initial success after the procedure (75%); however, in patients with partial success initially, only half (50%) were in sinus rhythm without inducibility of arrhythmias during the follow-up.

According to the study, similar mortality rates between 18% and 28% were observed during follow-up by authors Arya et al. [16], Kozeluhova et al. [8] and Jin et al. [25]; the main causes of death in these patients were the recurrence of ventricular arrhythmias or worsening of cardiac function. However, Bella et al. [19] and Deneke et al. [10] showed slightly lower mortality rates (9–10%); however, the causes related to death were the same as those found in other studies.

Nayyar et al. [7], in their meta-analysis (n = 471 cases), showed that only 6% of the patients had a recurrence of ES, and the recurrence of ES was even greater in patients without previous structural cardiomyopathy. In this same study during late follow-up (61 ± 37 weeks), 17% of the patients died (heart failure 62%, arrhythmias 23% and non-heart 15%) with 55% of deaths occurring within 12 weeks of the intervention. The failure of the initial procedure proved to be a predictor of mortality in this study.

3.6. Alternative methods

Surgically or percutaneously implanted mechanical circulatory support devices can provide hemodynamic support to allow for more detailed activation and entrainment mapping in patients with unstable VTs. The most common devices being used for mapping unstable ES include the percutaneous ventricular assist device (pVAD) (TandemHeart, Cardiac Assist, Inc., Pittsburg, PA, USA), the Impella microcirculatory axial blood flow pump (Abiomed, Inc., Danvers, MA, USA), the cardiopulmonary support (CPS) with bypass pump, and the intra-aortic balloon pump (IABP) [33–36].

Venoarterial extracorporeal membrane oxygenation (ECMO) is also helpful in supporting the respiratory system in addition to providing circulatory support. The major complications related to these devices are aortic valve avulsion, vascular injury, hematoma/pseudoaneurysm/retroperitoneal bleeding after device removal, and stroke/systemic embolism [36].

The use of surgery for the treatment of ES should be reserved for those refractory to drugs and catheter ablation where there is adequate surgical experience [19]; in this context, we have two main therapeutic modalities that involve the same theoretical concept, the sympathetic modulation of the nervous system to reduce the number of ventricular arrhythmias [28]. These modalities are represented by: Cardiac Sympathetic Denervation (CSD) and Renal Sympathetic Denervation (RDN).

Ajijola et al. [29] demonstrated the use of bilateral CSD as a possible therapy for six previously ablated ES patients, so that there was a complete response in 4 (66%) patients, a partial response in 1 (16.6%) patient and failure in the last one (16.6%). In addition, a significant reduction in the number of ICD therapies has been demonstrated. Vaseghi et al. [30] reported an analysis of 41 patients submitted to Left CSD or bilateral CSD. This study demonstrated that among the 14 patients submitted to L CSD, eight (57%) were alive and did not have recurrence of arrhythmias or ICD therapies during the first 90 days, but during the follow-up of 367 days, only 30% remained successful. However, in the group of patients submitted to bilateral CSD (27 patients), success was observed in 21 patients (77.8%) who were alive and free of recurrence and/or ICD therapies in the first 90 days, whereas during follow-up, only 13 (48%) individuals maintained success.

Regarding RDN, no human study was found in our sample. Scholz et al. [31] and Huang et al. [28] described RDN as a future therapy for decreasing sympathetic activity, thus reducing ventricular arrhythmias that would perpetuate ES.

4. Discussion

Ablation demonstrated its effectiveness in reducing the number of shocks in patients with ICD and ES, thus improving the morbidity and mortality of this group of patients [16]. The studies found similar results with regard to cardiovascular mortality that fit the findings found in other studies such as Multicenter Thermocool VT Ablation [32] This study demonstrated a 75% reduction in the number of shocks in 67% of patients with ICDs in their sample. In addition, the mortality presented by this study was 18%, and the two main causes of death were recurrence of ventricular arrhythmias and worsening of heart failure; these results show similarities with the data presented here.

The predictors of mortality in patients with ES are not presented uniformly by the studies; however, the early recurrence (<30 days) of ventricular arrhythmias and the indication for ablation because of the presence of ES are accepted by all authors as the main predictors (10,25). Other predictors such as CRF, LV dilation and severely reduced EF still require confirmation, and no relevance was found in their analysis by any of the authors.

Regarding the success of the procedure, the studies present results similar to those cited by Jin et al. [25] and Arya et al. [16]; these studies presented initial success in 75%–80% of the patients who were submitted to ablation with a previous indication of ES. However, the data presented by the articles regarding cardiovascular follow-up are not uniform. While Deneke et al. [10] and Arya et al. [16] observed that 69–70% of patients were free of recurrence during follow-up, Jin et al. [25], Kozeluhova et al. [8] and Kautzner et al. [21] presented more modest indexes varying between 47.5% and 55%; these rates are consistent with the results presented by Stevenson et al. [32] in their sample (49%). This variety of results may have a bias because of the analysis of data not specific to the patient's previous disease, considering that, in these studies, sampling is not limited to ischemic cardiomyopathy (ICM). In addition, Kozeluhova et al. [8], showed that although patients with structural heart disease are more likely to present ES, they present better prognostic indexes when adequately approached through ablative therapy with less arrhythmia recurrence after the procedure.

The therapeutic modality described by the articles presented here for the ICM approach was endocardial ablation], demonstrating superiority to the epicardial technique in patients with structural cardiopathy. This approach should be reserved for patients failing endocardial catheter ablation or the mapping indicates the epicardial arrhythmogenic focus. The selected studies showed better results in these situations. When it is used primarily, outside these criteria, the success rate is lower [1,14]. We have observed that the use of ablation in the treatment of electrical storm, today, is an increasingly common procedure, considering that the alternative methods have not proved as effective as the use of ablation associated with drug therapy. The duration of pharmacological treatment depends on each case and its severity, but should always be the first option before ablative treatment. The studies selected in this integrative review indicated that initial therapy in the electrical storm is drug therapy, most often using amiodarone or beta-blockers. They considered drug failure when used these medications and patients kept in electrical storm with hemodynamic instability, most of the time.

During the procedure, the anatomical electrocardiogram should be performed, with the option of LV access both by transseptal and transaortic routes. Although there was no formal indication for using these approaches, the majority chose to use the first approach. However, Pluta et al. [17] reiterated that in some patients, the mapping of septal areas through the septal pathway may be limited.

However, the isolated epicardial approach, CSD and RDN still have little evidence supporting their use as a primary approach in the treatment of ES in patients with structural heart disease. Arya et al. [6] questioned whether there would be a benefit for a dual approach (endo and simultaneous epicardial) in patients with ES; however, the sample of this study does not contemplate patients with ICM or any other structural heart disease, thus invalidating this questioning for our study. Regarding CSD, Ajijola et al. [29] presented a series of patients refractory to ablation, making it impossible for these results to be extrapolated to perform this procedure as a primary form of treatment for patients with ES. In our analysis, no relevant study was found addressing RDN.

4.1. Limitations

The limitations of this study are related to the lack of prospective studies addressing ablation in ES, the inclusion of only two databases and the inclusion of only the Portuguese and English languages.

5. Conclusion

Catheter ablation is the therapy of choice for patients with ES refractory to drug therapy, reducing their morbidity and mortality. The endocardial approach should be used initially, presenting more relevant success rates than the other therapeutic methods presented. Heart failure is the dominant cause of long-term death in patients with a successful procedure. The failure of the acute procedure entails high mortality.

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Conflict of interest

There is no conflict of interest.

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