MEDS Clinical Medicine (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/medsc.2023.040602
ISSN 2616-1907 Vol. 4 Num. 6

A Comparative Study of Acute Myocardial Infarction and Acute Cerebral Infarction

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Keywords: Acute myocardial infarction, Acute cerebral infarction, Direct aspiration, Thrombus removal

Abstract: Acute myocardial infarction (AMI) and acute cerebral infarction (ACI) are acute thrombotic diseases that occur in coronary artery and cerebrovascular, respectively. The timely opening of the infarct blood vessel was key to the rescue. Clinical treatment means include drug thrombolysis and mechanical thrombectomy. According to a series of relevant clinical controlled studies, direct aspiration and thrombectomy have become mainstream directions of development and application for acute cerebral infarction, while for AMI, whether routine thrombectomy is beneficial to patients is still debated. This paper compares and summarizes the published literature from the aspects of pathogenesis and clinical treatment of acute myocardial infarction and acute cerebral stroke, aiming to explore the similarities and differences in clinical treatment of acute myocardial infarction and acute cerebral stroke as well as the aspects that they can learn from each other, hoping to provide suggestions for clinical treatment.

1. Introduction

Acute cerebral infarction (ACI), one of the two major subtypes of stroke, is characterized by disruption of cerebral blood flow and subsequent neurological disorders, mainly due to atherosclerosis or cardiogenic embolism. Rapid reperfusion of cerebral arteries is essential to reduce tissue damage and improve prognosis in clinical treatment. However, due to strict time window limitations and the risk of systemic bleeding, most patients do not benefit from drug thrombolytic therapy with rt-PA. Direct aspiration thrombectomy has been reported as an effective mechanical therapy to remove clots without damaging the artery. Based on a series of controlled clinical studies, minimally invasive mechanical thrombectomy through catheterization is recommended for patients at home and abroad [1].

Acute myocardial infarction (AMI) is caused by coronary artery blockage caused by atherosclerotic plaque rupture, which leads to myocardial ischemia and hypoxia and necrosis. Rapid opening of the infarcted coronary artery is the key to treatment. Initial percutaneous coronary intervention (PCI) remains the preferred reperfusion strategy [1]. Different from ACI, drug-eluting stent implantation is recommended for AMI, and manual thrombus aspiration can be applied to AMI patients with large thrombotic load, because thrombus aspiration may reduce the local thrombotic load, minimize the pre-dilation need of balloon, promote direct stent implantation, reduce the occurrence of distal embolism, and ultimately improve myocardial reperfusion [2]. The efficacy of routine thrombus aspiration in AMI patients is highly debated, but manual thrombus aspiration remains a common treatment strategy used by interventional physicians in the treatment of both fresh and high-load thrombus.

A series of relevant controlled clinical studies have shown that direct aspiration and thrombectomy have become mainstream directions of development and application for ACI. However, whether aspiration thrombectomy should be used as a routine treatment for AMI is still under debate. Also, acute arterial embolism disease, AMI and ACI share many similarities as well as many differences, which requires a comparison of clinical and research developments and characteristics from both pathogenesis of the disease and clot properties.

2. Difference of composition of the thrombus between ACI and AMI

The composition of blood clots is heterogeneous and measured in terms of incidence and mortality. The thrombus in patients with ST-elevation myocardial infarction (STEMI) is mainly composed of fibrin and other components [3]. Silvain et al. have shown that the amount of fibrin in blood clots increases over time in STEMI patients, while the number of platelets decreases [4]. The thrombus in the left anterior descending branch contained more platelets, while the proportion of red blood cells in the right coronary artery was higher [5]. Because coronary atherosclerosis has fragment, most STEMI are platelet-rich blood clots that form in situ and are not easily cleared by a suction catheter [6,7]. Clots in patients with ACI, both cardiac and non-cardiac, are associated with clots rich in fibrin, and clots tend to be red blood cell-rich and non-cardiac.[4]. Studies have shown that thrombus rich in red blood cells is associated with thrombus migration, and fibrin-rich thrombus is associated with stable and late thrombus formation [5]. Recent studies of the characteristics of thrombus in acute cerebral infarction have shown that the histological, biochemical, and structural composition of blood clots respond completely differently to mechanical thrombectomy [8]. Erythrocyte-rich thrombus is generally associated with good outcomes, which may be attributed to its physical properties of reduced hardness and increased deformability, because fibrin hardness increases over time, fibrin-rich thrombus responds poorly to thrombectomy [9,10].

In general, fibrin-rich thrombus requires a combination of thrombectomy devices to achieve vascular recanalization. The composition of the clot is related to its origin and etiology, and fibrin-rich clots show a reduced recirculation rate regardless of the technique. In addition, mature thrombus rich in fibrin are stronger and less deformable in their interaction with the stent recovery device, and this reduced deformability correspondingly increases the friction between the thrombus and the vessel wall, resulting in less effective thrombus recovery each time [11]. Since most cerebral thrombus are ectogenic thrombus rather than in-situ thrombus, it is easier to catch and clear with a catheter than in-situ thrombus caused by the rupture of atherosclerosis in AMI patients. Therefore, clinical treatment of ACI can benefit from thrombus aspiration, while STEMI has a negative result [12]. The changes in the composition of the thrombus may have important implications for mechanical thrombectomy and thrombolysis, and further studies are needed to understand the mechanisms responsible for the structural changes in the thrombus.

3. Clinical treatment and development

Coronary interventional therapy was first proposed in the 1970s, and the world's first interactive percutaneous coronary angioplasty was completed in 1997, marking a new stage in the AMI treatment [6]. The latest guidelines state that the preferred strategy for reperfusion in ACI treatment remains to be PCI [7]. The golden standard for the treatment of STEMI patients with second-generation drug-eluting stents has resulted in a significant reduction in the incidence of immediate and late adverse events [8]. PCI in STEMI patients often fails due to incomplete myocardial reperfusion of microvascular vessels, possibly due to microvascular blockages caused by distal thromboembolism, and affects the prognosis. In order to solve the problem of poor myocardial perfusion after PCI, many microcirculation protection devices have been developed, such as distal embolic protection devices, mechanical thrombectomy, and direct aspiration [9].

In the clinical treatment of ACI, although current guidelines recommend that rt-PA intravenous thrombolysis be performed within 4.5h of symptom onset, it is far from a perfect treatment due to the limitations of the time window and contraindications and considering the serious risks associated with thrombolysis [10]. Subsequently, from intra-arterial thrombolysis to increasingly effective thrombolysis devices, mechanical thrombectomy, mainly based on ADAPT, a new generation of direct suction thrombolysis, has become increasingly popular in the ACI treatment, bringing many benefits to patients (shortening surgical time, reducing costs, improving thrombolysis efficiency, etc.) [11]. Results of in vitro experiments show that different devices can produce very different thrombus removal effects [12].

3.1 Mechanical thrombectomy

For coronary artery thrombosis including manual aspiration and mechanical aspiration, there are currently three kinds of manual aspiration catheters commonly used, namely ZEEK (widely used), Diver-CE and EXport. These three thrombus aspiration catheters can be rapidly exchanged and can be used with the 6F catheters without the need for complicated mechanical devices. It can also be used with clinical routine wires [9]. It is characterized by simple structure and operation and low clinical cost, but also suffers from poor tracking and extrapolation performance. The only catheter with side holes, Diver-CE, has a small suction inner diameter and is highly likely to push the thrombus fragment to the distal end, reducing the effectiveness of suction [13].

The mechanical aspiration devices are X-sizer and AngioJet [14]. X-sizer uses a spiral cutting blade at the distal end of a catheter to cut the clot and then vacuum it out of the body, but there is a risk of coronary artery rupture [9]. In 1997, the United States food and drug administration (FDA) approved the first generation AngioJet mechanical suction device listed. In 2006, the FDA approved AngioJet, the second-generation mechanical device on the market. In 2012, AngioJet won the China state food and drug administration (SFDA) [15] for approval. AngioJet uses the Bernoulli principle to remove intravascular thrombosis by hydrostatic aspiration without expanding the underlying plaque and prepares the vessel for subsequent safe and simple interventions, including stent placement. In acute myocardial infarction with total occlusion, the amount of thrombus or the severity of the underlying stenosis cannot be accurately assessed, so the AngioJet catheter may not be able to pass through the vessel lesion. Despite these limitations, AngioJet can still successfully clear the thrombus from the coronary artery and facilitate subsequent stent implantation [20]. During direct PCI, the AngioJet is the best option for patients with high thrombosis load, while manual aspiration catheters are used for patients with low thrombosis load. If manual aspiration catheter is not effective, AngioJet mechanical thrombus aspiration device can still be selected for thrombus aspiration [9].

Mechanical thrombus aspiration catheter is more thorough than artificial thrombus aspiration catheter in removing thrombus, but studies have found that the application of mechanical thrombus aspiration will lead to an increase in infarct size, etc., and the design of mechanical aspiration is complicated, the operation is difficult, and the price is expensive, so it is rarely used at present [25][21].

Clinical representatives of mechanical thrombectomy for cerebral thrombectomy are MERCI, the first generation of 2004, which is a helical wire thrombectomy similar to a wine opener. The second generation of the 2009 PENUMBRA Splitter removes the clot by separating the splitter head and then extracting it through a syringe or suction pump. In 2012, the third-generation STENTRIEVER, a self-expanding wire mesh delivered via a microcatheter, pulls on the clot and removes it [14]. The latest generation of ADAPT thrombectomy, developed in 2013, is completely based on suction compared to the previous three generations, which can push the catheter with a larger inner diameter directly to the clot for direct suction, avoiding mechanical extrusion and mechanical failure, and bringing good benefits and cost savings to patients. Therefore, direct suction is widely used in clinical practice [15].

3.2 Whether to preferentially use thrombus aspiration

For patients with AMI, selective aspiration before stent implantation in patients with heavy thrombotic load or remedial aspiration when distal embolism occurs is the correct strategy to reduce distal embolism events [16]. In patients with long ischemia time, small vessels, and low thrombotic load, thrombus aspiration may be of little significance, and balloons may be used in vasodilator surgery on a small-to-large principle. However, for patients with high-load thrombus, large vessel diameter, and proximal lesions, thrombus can be extracted with thrombus aspiration catheter before selecting appropriate balloon, accurately judging the timing of catheter withdrawal, and maintaining continuous flow, and then the blood flow condition and residual thrombus load of the blood vessel can be used as the basic basis [17]. Removal of blood clots can lead to more suitable stent selection, positioning and release, the effect of mechanical suction is more thorough than manual suction, and the relatively bulky and complex mechanical suction device restricts its further application [29]. The new guidelines for AMI recommend a clear preference for the radial artery approach sites. Since Campeau, a Canadian doctor, reported that coronary angiography was performed through the radial artery approach, a large number of experimental studies have confirmed the feasibility and superiority of PCI treatment through the radial artery approach [18].

There are two techniques that can be used for acute cerebral infarction intravascular therapy: stent recovery with or without a suction catheter, and a suction plug using a suction catheter alone, with the potential for adjuvant therapy if recalculation is not initially achieved [19]. Stent thrombectomy can be used across the stenosis segment and may be the preferred treatment when the occlusion is located at the distal end of severe acute angulation [20]. A combination of Adapt and stents is commonly used in patients with long segment occlusion [21]. With Adapt as the first-line treatment, a mechanical thrombectomy commonly used by neurointerventional physicians, the catheter is directed to the target proximal blood vessel. With the help of a microcatheter and microfilaments, a perforated aspiration catheter is navigated inside the skull to the proximal part of the clot. Once in place, the aspiration catheter is then connected to the aspiration system (pump or negative pressure syringe). Slowly withdraw the suction tube. In acute cerebral infarction, mechanical thrombectomy is usually performed through the femoral artery approach [22]. The combination of a new generation of suction tubes and a vacuum suction system may produce higher suction and further improve the reproducibility of direct aspitation, but there are concerns about the navigability and traceability of the technology, and further research is needed to improve efficiency and safety [35].

3.3 Thrombotic fragments

Adapt is a simple and effective method for removing clots in acute cerebral infarction patients, but downstream clot fragments are experienced during the procedure, and they are usually macromolecular fragments located in the proximal branch that can be removed with an initial 5 Max or 3 Max catheter [23]. This is in contrast to the approach used with separators, where the fragments appear to be micromolecular and stay in a myriad of small distal branches that are not suitable for mechanical thrombolysis, and also have less potential for lateral branching [24]. Adapt raises the bar for interventional neurologists, who are no longer satisfied with simply achieving recanalization, but should instead focus on achieving optimal recanalization to maximize the well-being of their patients. This means that we need to pay attention to the downstream embolus impact on the relevant area, as has been reported in vitro models and in the clinic, where Adapt technology is notable for its ability to often clear all or large fragments of offending thrombus at the end of the aspiration catheter [25]. The anatomical and technical aspects of the intervention, where the coronary arteries are constantly moving and the heart is constantly beating, can increase the difficulty of the operation. Brain arteries do not move, thereby facilitating interventions that require physicians to understand and study the anatomy of blood vessels. Loss of small branches in AIM patients usually does not affect the overall prognosis of patients, but loss of small branches in acute cerebral infarction patients will seriously affect the vital function of patients [26]. Therefore, thrombotic fragments in patients with acute cerebral infarction must be attended to and removed in a timely manner.

4. Time window and vascular characteristics

The effectiveness of coronary intervention varies in different time Windows, with symptoms of STEMI onset occurring within the first 12 hours, suggesting that PCI (performance target ≤90 minutes from the first medical contact) is the preferred approach [27]. Primary PCI is associated with lower rates of early mortality, recurrence, and intracranial hemorrhage than IV. However, when PCI is delayed for more than 2 hours, thrombolysis should be performed first, if no contraindications are available, and transfer to a PCI capable facility should be routinely considered within the following 3 to 24 hours [28] [29]. Early coronary intervention therapy in patients with AIM is better at reducing the occurrence of adverse cardiovascular events when the treatment is more effective.

Current guidelines recommend that acute cerebral infarction be treated with drug thrombolysis within 4.5 hours of symptom onset, and that good functional outcomes are twice as good when acute cerebral infarction begins thrombolysis within 6 hours [30]. A study by Bourcier et al. showed that reperfusion success decreased with time to stroke after reaching the intravascular center [31]. Data from a meta-analysis showed a significant correlation between clinical outcomes and the time interval to reach recanalization [32]. Although the treatment window for thrombectomy (<6 hours) is larger than that for thrombolytic therapy (<4.5 hours), it is critical to begin preparing eligible patients for thrombectomy intervention soon after stroke onset because favorable outcomes rapidly diminish over time [33].

5. Epidemiology

Even with the decline in age-adjusted mortality from cardiovascular disease, AMI prevalence and mortality are more common in the elderly than in the middle-aged population, and the median age of AMI is currently around 65 and will increase further. Effective recanalization of the infarcted artery in patients treated with mechanical thrombectomy is high (approximately 90%), and 30-day mortality has decreased from more than 20% to less than 5% with widespread use of reperfusion therapy for STEMI [35]. Compared with men, women who receive less inappropriate treatment during AMI have worse outcomes than men with either thrombolytic therapy or PCI strategy, with higher morbidity and mortality when treated with thrombolytic drugs, in part due to confounding by risk factors such as age, diabetes, hypertension, and heart failure [36]. Data show that compared with elderly patients, young patients are more likely to have left anterior descending artery related myocardial infarction [37][38]. Residual coronary stenosis may prevent adequate reflow of the offending vessel, leading to ischemia or infarction, which can be prevented by mechanical dilation of the vessel [39].

It has been reported that younger patients have a shorter time from stroke to clot exposure, which has a positive effect on aspiration success. One speculative explanation may be that a longer delay after stroke onset may promote the biological interaction between the clot and the artery wall, leading to firmer adhesion, which could explain the aspiration failure [31].

6. Discussion

Acute myocardial infarction (AIM) and acute cerebral infarction (ACI) are both acute vascular thrombotic diseases with high mortality and disability rates. The clinical treatment principles for both diseases are drug thrombolysis and mechanical thrombectomy. Due to differences in thrombosis mechanisms and vascular anatomy, there are differences in the order and selection of aspiration catheters, treatment time windows, and vascular characteristics. Thrombus in AIM is in-situ thrombus formed by rupture of atherosclerotic plaque, which is rich in fibrin and is not readily cleared by aspiration catheters. This explains why the aspiration catheter for the coronary artery has a side hole and the catheter needs to be inserted and in contact with the thrombosis for aspiration. Therefore, thrombus aspiration in AIM therapy can be used as a remedial adjunct to stent placement rather than a routine option. Thrombus in acute cerebral infarction is caused by non-in situ thrombus from elsewhere, which is rich in red blood cells and easily removed by aspiration catheters. Direct aspiration has become a mainstream direction of development and application in acute cerebral infarction.

For ACI, direct aspiration and clot removal is achieved by negative pressure aspiration through an external vacuum pump. For AngioJet, a mechanical thrombectomy catheter used in AIM, the thrombus is crushed by a high-velocity jet fluid based on the Bernoulli principle. Can it be used for aspiration and thrombus removal of cerebral artery thrombus? Similarly, whether the aspiration cathether for cerebral thrombus can be used for coronary thrombus removal requires in vitro simulation trials and a large number of clinically relevant controlled studies to solve this question. Whether it is coronary thrombus or cerebral thrombus, the principle of thrombus aspiration device is not different. This idea can be tested by further in vitro simulation experiments to see if an optimal aspiration catheter head can be designed to accommodate coronary thrombus and cerebral thrombus.

7. Conclusion

This paper compares and analyzes the pathogenesis, thrombus composition, clinical treatment development and other aspects of Acute myocardial infarction (AIM) and acute cerebral infarction (ACI), and analyzes the similarities and differences between the two diseases as well as the aspects that can be learned from each other. Both diseases involve drug thrombolysis and mechanical thrombectomy, but they are so different that it is worthwhile to investigate the similarities and differences between the two diseases in depth.

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