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THE IMPORTANCE OF TIME TO INTERVENTION IN RUPTURED AB-DOMINAL AORTIC ANEURYSM TIME TO INTERVENTION IN rAAA - NARRATIVE REVIEW

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ABSTRACT

Ruptured abdominal aortic aneurysm (rAAA) remains one of the most formidable emergencies in vascular surgery and continues to be associated with substantial mortality and morbidity de-spite major advances in diagnostic imaging, perioperative management, anesthesia, and endo-vascular therapy. The clinical challenge lies not only in the catastrophic nature of the rupture itself, but also in the narrow temporal window available for diagnosis, transfer, and definitive hemorrhage control. Contemporary pathway-based care models therefore emphasize that treatment should follow diagnosis with the least possible delay, and many systems operationalize this urgency through a target intervention interval of 90 minutes or less.

Over the past three decades, the management of rAAA has evolved substantially through im-proved imaging availability, greater use of coordinated transfer networks, more selective pre-hospital and early in-hospital resuscitation strategies, better patient selection for open and endo-vascular repair, implementation of standardized emergency pathways, and increased awareness of major postoperative complications such as renal failure, abdominal compartment syndrome, and multiorgan dysfunction. These developments, together with advances in perioperative physiological optimization and critical care support, have contributed to gradual improvement in reported outcomes in modern series. Nevertheless, postoperative morbidity and mortality re-main high, and contemporary reports still describe substantial death rates among treated patients. Only a minority of patients appear to undergo definitive repair within the recommended time window, underscoring the persistent gap between guideline-driven expectations and real-world emergency system performance. Although current evidence suggests that the ≤90-minute benchmark may have limited independent association with postoperative morbidity and mortality after adjustment for baseline risk and hemodynamic status, avoiding unnecessary delay re-mains a central principle of rAAA care. Time to intervention should therefore be understood not merely as a numerical target, but as a marker of system efficiency, diagnostic speed, transfer coordination, and readiness to deliver definitive treatment in a critically unstable patient.

KEYWORDS

Ruptured Abdominal Aortic Aneurysm; Time to Intervention; Treatment Delay; Endovascular Aneu-Rysm Repair; Open Repair; Transfer Networks; Vascular Emergency; Mortality; Perioperative Care; Regionalization

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1. Introduction

Ruptured abdominal aortic aneurysm (rAAA) remains one of the most severe and time-sensitive emergencies in vascular surgery, and it continues to be associated with substantial mortality despite major advances in diagnostic imaging, perioperative care, and endovascular repair techniques (Chaikof et al., 2018; Modern Management of Ruptured Abdominal Aortic Aneurysm, 2023; The Management of Ruptured Abdominal Aortic Aneurysms, 2023). The condition represents the catastrophic end point of a progressive vascular disease process, and once rupture occurs, survival depends on rapid recognition, hemodynamic stabilization, and definitive hemorrhage control (Abdominal Aortic Aneurysm: A Comprehensive Review, 2011; Chaikof et al., 2018). In the absence of timely surgical or endovascular intervention, spontaneous survival is exceptionally uncommon, and persistent hypotension rapidly contributes to tissue hypoperfusion, metabolic acidosis, coagulopathy, multi-organ dysfunction, and death (The Management of Ruptured Abdominal Aortic Aneurysms, 2023; Modern Management of Ruptured Abdominal Aortic Aneurysm, 2023). For this reason, early definitive repair is central not only to restoring aortic integrity but also to limiting the physiologic cascade that drives postoperative complications and poor outcomes (Chaikof et al., 2018; Reimerink et al., 2013).

Contemporary clinical guidance consistently frames rAAA as a true emergency in which treatment should follow diagnosis as quickly as possible (Abdominal Aortic Aneurysm: Diagnosis and Management, 2020; Chaikof et al., 2018). Many centers and regional systems have adopted an intervention target of within 90 minutes of presentation or diagnosis, reflecting the belief that minimizing delay is essential to improving outcomes (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). However, real-world practice often falls short of this ideal (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). Only a minority of patients are treated within the recommended window, and available evidence suggests that the ≤90-minute benchmark, although biologically plausible and operationally useful, has limited independent association with postoperative morbidity and mortality once patient condition and case complexity are considered (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). This does not reduce the importance of rapid care; rather, it suggests that timing must be interpreted in context, alongside hemodynamic status, rupture severity, anatomic suitability for repair, and the logistical realities of emergency vascular care (Mell et al., 2017; The Management of Ruptured Abdominal Aortic Aneurysms, 2023).

The management of rAAA has also changed substantially over the past three decades (Powell et al., 2014; Reimerink et al., 2013; Wang et al., 2020). The wider availability of endovascular aneurysm repair, greater centralization of vascular services, development of transfer networks, and implementation of standardized clinical pathways have all reshaped the treatment of this condition (Mell et al., 2017; Wang et al., 2020; Takei et al., 2023). In parallel, improvements in pre- and postoperative physiologic resuscitation, blood product management, anesthesia, and critical care have contributed to gradual improvement in reported outcomes in modern series (Modern Management of Ruptured Abdominal Aortic Aneurysm, 2023; The Management of Ruptured Abdominal Aortic Aneurysms, 2023). Nevertheless, mortality and morbidity remain high, underscoring the need for continued emphasis on early diagnosis, efficient transfer, timely intervention, and coordinated multidisciplinary care (Kontopodis et al., 2021; The IMPROVE Investigators, 2017). Against this background, the role of time to intervention remains a central theme in understanding and improving the management of rAAA (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020).

2. Epidemiology and Risk

Ruptured abdominal aortic aneurysm (rAAA) represents the most catastrophic clinical manifestation of abdominal aortic aneurysm disease and remains a major cause of death in vascular surgery (Chaikof et al., 2018; Kent et al., 2010; Scali et al., 2023). Although the overall incidence of abdominal aortic aneurysm (AAA) has been influenced by changes in smoking prevalence, screening practices, and cardiovascular risk management, rupture continues to occur and remains associated with very high mortality (Chaikof et al., 2018; Cornuz et al., 2004; Kent et al., 2010). In many patients, aneurysms remain clinically silent until they enlarge significantly or rupture, meaning that the first presentation may be an acute vascular emergency rather than elective detection during surveillance (Chaikof et al., 2018; National Institute for Health and Care Excellence [NICE], 2020). For this reason, the epidemiology of rAAA is closely linked not only to aneurysm prevalence but also to underdiagnosis, delayed detection, and unequal access to screening and specialist care (ACR Appropriateness Criteria® Screening for Abdominal Aortic Aneurysm, 2024; NICE, 2020).

The development and rupture of AAA are associated with a number of well-established risk factors (Cornuz et al., 2004; Risk Factors for Abdominal Aortic Aneurysm in General Populations, 2025). Advanced age remains one of the most important non-modifiable factors, with most aneurysms occurring in older adults (Cornuz et al., 2004; Forsdahl et al., 2009). Male sex is strongly associated with aneurysm formation, and the disease is considerably more common in men than in women (Cornuz et al., 2004; Smoking, Sex, Risk Factors and Abdominal Aortic Aneurysms, 2015). However, although women develop AAA less frequently, rupture appears to occur at smaller aneurysm diameters and may be associated with worse outcomes once rupture occurs. This observation has important clinical implications because it suggests that risk assessment based purely on diameter thresholds may underestimate rupture risk in female patients (Lo et al., 2014; Reconsidering Gender Relative to Risk of Rupture in the Abdominal Aortic Aneurysm, 2015).

Smoking is widely regarded as the strongest modifiable risk factor for both AAA formation and rupture (Cornuz et al., 2004; Tobacco Smoking and the Risk of Abdominal Aortic Aneurysm, 2018). Its association with aneurysm disease is stronger than that observed for many other cardiovascular conditions, and smoking contributes not only to aneurysm development but also to faster expansion and increased rupture risk (Norman & Curci, 2013; Smoking, Sex, Risk Factors and Abdominal Aortic Aneurysms, 2015). Hypertension, atherosclerotic disease, chronic obstructive pulmonary disease, renal dysfunction, hyperlipidemia, and a positive family history also contribute to aneurysm development and progression (Risk Factors Associated With the Diagnosis of Abdominal Aortic Aneurysm, 2014; Risk Factors for Abdominal Aortic Aneurysm in General Populations, 2025). In many patients presenting with rAAA, these risk factors coexist, creating a population that is often physiologically vulnerable even before the onset of hemorrhagic shock (Kent et al., 2010; Scali et al., 2023).

Aneurysm diameter remains the most clinically relevant anatomical predictor of rupture (Chaikof et al., 2018; Lo et al., 2014). Larger aneurysms carry a substantially greater risk of rupture than smaller aneurysms, and diameter continues to guide surveillance and elective treatment decisions (Chaikof et al., 2018; NICE, 2020). Nevertheless, rupture cannot be understood through diameter alone (Kent et al., 2010; Lo et al., 2014). Aneurysm morphology, wall stress, inflammatory activity, intraluminal thrombus, blood pressure, and patient-specific biological factors may all contribute to rupture risk (Kent et al., 2010; Lo et al., 2014). As a result, some aneurysms rupture below traditional treatment thresholds, whereas others remain stable despite large size (Lo et al., 2014; Reconsidering Gender Relative to Risk of Rupture in the Abdominal Aortic Aneurysm, 2015). This variability explains why rupture risk is best understood as multifactorial rather than purely size-dependent (Lo et al., 2014; Risk Factors for Abdominal Aortic Aneurysm in General Populations, 2025).

From a systems perspective, the epidemiology of rAAA also reflects the limitations of screening and prevention strategies (ACR Appropriateness Criteria® Screening for Abdominal Aortic Aneurysm, 2024; NICE, 2020). In patients who are not screened, are not under surveillance, or do not meet current screening criteria, aneurysm disease may remain undetected until rupture occurs (ACR Appropriateness Criteria® Screening for Abdominal Aortic Aneurysm, 2024; NICE, 2020). This is particularly relevant in women and in other under-recognized risk groups, where current screening approaches may not fully capture the true disease burden (Meta-analysis of the Current Prevalence of Screen-Detected Abdominal Aortic Aneurysm in Women, 2016; Reconsidering Gender Relative to Risk of Rupture in the Abdominal Aortic Aneurysm, 2015). Consequently, rAAA continues to place a significant burden on emergency healthcare systems because patients often present suddenly with hemodynamic instability, severe pain, or collapse and require urgent diagnosis and treatment under extreme time pressure (Scali et al., 2023; Troisi et al., 2023).

Understanding the epidemiology and risk profile of rAAA is therefore essential not only for prevention but also for emergency management (Chaikof et al., 2018; NICE, 2020). Patients who rupture are often older, comorbid, and physiologically fragile, and these characteristics strongly influence both their ability to survive the rupture itself and their capacity to tolerate definitive treatment (Outcomes After Open Repair of Ruptured Abdominal Aortic Aneurysms in Octogenarians, 2014; Troisi et al., 2023). The epidemiological context of rAAA thus provides an important framework for interpreting the significance of time to intervention because delays may have different consequences depending on the patient's baseline risk, hemodynamic condition, and anatomical suitability for repair (Kontopodis et al., 2021; Mell et al., 2017).

3. Definition of Time to Intervention

Time to intervention in ruptured abdominal aortic aneurysm (rAAA) is not a single standardized metric. In the literature, it may refer to the interval from diagnosis to definitive repair, from hospital arrival to the start of treatment, or to the broader door-to-intervention period that includes evaluation, imaging, transfer, and operative preparation (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). This lack of uniformity makes comparisons across studies difficult and can lead to different interpretations of the same clinical pathway (Kontopodis et al., 2021; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020).

In many contemporary pathways, the goal is to keep door-to-intervention time below 90 minutes (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). That target is often linked to the "30-30-30" concept, which divides the emergency pathway into rapid recognition and assessment, transfer or imaging, and definitive operative management (Mell et al., 2017). The logic behind this model is straightforward: rupture remains active until aortic control is achieved, so each additional step before repair has the potential to worsen shock and organ ischemia (Chaikof et al., 2018; Scali et al., 2023).

The problem is that the term "time to intervention" does not always measure the same phase of care. In some reports, it begins at first medical contact; in others, it starts at hospital arrival or after diagnosis is confirmed. Some studies include time spent in transfer, imaging, or operating room preparation, while others isolate only the time to incision or endograft deployment (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Mell et al., 2017). Because of this heterogeneity, the same phrase may describe very different clinical realities (Kontopodis et al., 2021).

This matters clinically because a longer interval is not always inappropriate. A patient may require CT angiography to define anatomy for EVAR, stabilization before anesthesia, or transfer to a specialist vascular center (Chaikof et al., 2018; Wang et al., 2020). In those settings, the interval before intervention reflects necessary care rather than avoidable delay (Mell et al., 2017; Scali et al., 2022). For that reason, time to intervention should be interpreted as part of the whole emergency pathway, not as a single isolated number (Kontopodis et al., 2021).

A useful distinction can be made between avoidable and unavoidable delay. Avoidable delay includes diagnostic hesitation, repeated handoffs, inefficient communication, and poor coordination between departments or hospitals. Unavoidable delay may result from the time needed for imaging, referral, transfer, blood product preparation, or mobilization of a vascular team (Mell et al., 2017; Scali et al., 2022). The clinical challenge is therefore not simply to make the clock run faster, but to reduce delays that do not improve patient safety or treatment quality (Kontopodis et al., 2021; Takei et al., 2023).

4. Why Timing Matters in Ruptured Abdominal Aortic Aneurysm

Time to intervention is central in ruptured abdominal aortic aneurysm because the condition is driven by active hemorrhage, and the longer bleeding continues, the more likely the patient is to develop shock, acidosis, coagulopathy, and irreversible organ injury (Chaikof et al., 2018; Scali et al., 2023; Troisi et al., 2023). In practical terms, every minute before aortic control increases the chance that the patient will move from a potentially salvageable state to profound physiologic collapse (Chaikof et al., 2018; Reimerink et al., 2013).

This is true even when the patient seems temporarily stable. A normal blood pressure at presentation does not mean the rupture is mild or that the patient is safe to observe, because compensatory vasoconstriction and transient hemodynamic buffering can mask ongoing blood loss (Scali et al., 2023; Troisi et al., 2023). Stable patients may actually be at special risk of delay, since the appearance of stability can reduce urgency in triage, imaging, transfer, and operating room activation (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020).

The physiology explains why delay matters so much. Ongoing bleeding reduces tissue perfusion, which worsens lactate accumulation, renal ischemia, myocardial strain, and respiratory compromise (Chaikof et al., 2018; Troisi et al., 2023). Once shock becomes prolonged, the patient may enter a self-reinforcing cycle in which acidosis, coagulopathy, and hypothermia amplify each other and make successful repair harder even if surgery eventually occurs (Scali et al., 2023; Reimerink et al., 2013).

Timing also matters because rAAA care is not just a surgical event; it is a systems problem. The interval from diagnosis to repair reflects whether the emergency pathway is functioning efficiently, whether vascular surgery is activated early, whether the correct operation is chosen quickly, and whether transfer or imaging creates avoidable delay (Mell et al., 2017; Scali et al., 2022; Takei et al., 2023). In that sense, time to intervention is both a biologic variable and a marker of team performance (Kontopodis et al., 2021; Mell et al., 2017).

The most useful interpretation of timing is therefore not as a single rigid cutoff, but as a way to reduce preventable delay. A strict universal threshold cannot capture every difference in anatomy, physiology, or logistics, but a shorter pathway generally improves the chance of repairing the rupture before irreversible organ damage develops (Kontopodis et al., 2021; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). That is why modern rAAA care emphasizes early suspicion, rapid escalation, and definitive control of hemorrhage as quickly as safely possible (Chaikof et al., 2018; NICE, 2020; Troisi et al., 2023).

5. Impact of Treatment Delay on Morbidity and Mortality

The effect of treatment delay on outcomes in ruptured abdominal aortic aneurysm (rAAA) is clinically significant, but the literature does not support a simple linear relationship between elapsed time and mortality in every patient. Contemporary registry-based studies have shown that a substantial proportion of patients do not receive repair within the commonly cited 90-minute door-to-intervention window, and only a limited number of centers consistently meet this target (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Mell et al., 2017). In one major registry analysis, treatment within 90 minutes was not independently associated with a clearly lower risk-adjusted 30-day mortality rate after either open repair or EVAR (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). This finding is important because it suggests that outcomes after rAAA cannot be interpreted through a single timing threshold alone. Survival is instead shaped by a combination of factors, including the severity of hemorrhagic shock, the patient's physiologic reserve, aneurysm anatomy, treatment modality, and the experience and organization of the treating center (Kontopodis et al., 2021; Wang et al., 2020; The IMPROVE Investigators, 2017).

At the same time, the absence of a strong independent association in one adjusted model should not be interpreted as evidence that delay is irrelevant. Older observational studies and clinical series have repeatedly suggested that longer time to surgery is associated with poorer survival, especially when delays occur in patients who are already physiologically unstable (The Effect of Patient Transfer on Outcomes After Rupture of an Abdominal Aortic Aneurysm, 2007; Impact of Interfacility Transfer of Ruptured Abdominal Aortic Aneurysm Patients, 2022). In these cases, time is not simply a neutral variable measured in minutes; it is the period during which blood loss continues, perfusion worsens, acidosis deepens, and compensatory mechanisms fail (Chaikof et al., 2018; Troisi et al., 2023). The longer that rupture remains uncontrolled, the greater the likelihood that the patient will shift from a potentially salvageable condition into irreversible shock (Scali et al., 2023; Troisi et al., 2023). Even when this deterioration is not captured fully by statistical models, it remains clinically meaningful at the bedside (Chaikof et al., 2018).

The effect of delay on morbidity is similarly multifactorial rather than linear. Postoperative complications after rAAA reflect the interaction between the duration of hemorrhage, the magnitude of preoperative shock, the inflammatory and ischemic burden of rupture, and the technical complexity of the repair itself (Reimerink et al., 2013; Powell et al., 2014). Prolonged untreated rupture can worsen myocardial stress, renal injury, respiratory dysfunction, coagulopathy, and ischemia-reperfusion injury, all of which may continue after definitive repair and contribute to prolonged intensive care unit stay (Chaikof et al., 2018; Troisi et al., 2023). Abdominal compartment syndrome, need for massive transfusion, and multiple organ dysfunction are also more likely in patients who have been exposed to more severe or more prolonged circulatory collapse (Scali et al., 2023; Takei et al., 2023). For this reason, the clinical importance of treatment timing extends beyond crude survival alone and includes postoperative recovery, complication burden, and resource utilization (Kontopodis et al., 2021; Takei et al., 2023).

A particularly important issue is that hemodynamically stable patients may not behave as intuitively expected. Several reports suggest that patients who appear normotensive or only mildly unstable may experience longer door-to-surgery intervals than those in frank shock (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Mell et al., 2017). This pattern likely reflects human and system-level behavior: temporary stability may reduce perceived urgency, slow escalation, or encourage additional diagnostic steps before definitive activation of the vascular pathway (Mell et al., 2017; Scali et al., 2023). Yet such stability can be deceptive, because rAAA may deteriorate abruptly after a short period of compensation (Troisi et al., 2023). In practical terms, the patient who seems "less sick" may actually be the one most vulnerable to preventable delay. This makes timing especially important in the subgroup of patients who do not immediately trigger maximal alarm at presentation (Chaikof et al., 2018).

The lack of a consistent mortality signal for a single benchmark should therefore be interpreted cautiously. A 90-minute target may be too crude to capture the complexity of rAAA care, but it still has operational value because it highlights when the emergency system is slow, fragmented, or unnecessarily delayed (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). It may also fail to show a strong independent effect in multivariable analyses because delay is often entwined with illness severity: the sickest patients may be treated fastest, yet still have the worst outcomes because they start from a more unstable physiologic position (Kontopodis et al., 2021; Wang et al., 2020). That does not weaken the importance of rapid intervention; rather, it shows that timing must always be interpreted together with hemodynamics, anatomy, and treatment selection (Chaikof et al., 2018; The IMPROVE Investigators, 2017).

Ultimately, the literature supports a balanced conclusion. The ≤90-minute benchmark should not be viewed as a perfect prognostic rule, but neither should it be dismissed as meaningless. Time to intervention is better understood as a marker of pathway efficiency and clinical urgency, with its greatest value lying in the detection of avoidable delay (Mell et al., 2017; Kontopodis et al., 2021). In that sense, the goal is not to prove that every patient benefits in a uniform statistical way, but to ensure that no patient loses the chance of survival because of preventable inefficiency. For rAAA, speed matters because physiology is unforgiving, and the window for successful intervention can close quickly once hemorrhage and shock advance (Chaikof et al., 2018; Troisi et al., 2023).

6. Transfer and Regionalization

Interhospital transfer and regionalization are major components of modern ruptured abdominal aortic aneurysm (rAAA) care and are closely tied to the broader question of time to intervention (Mell et al., 2017; Scali et al., 2022). In many healthcare systems, patients with suspected or confirmed rAAA first present to hospitals that do not have immediate vascular surgery or endovascular aneurysm repair (EVAR) capability (Mell et al., 2017; Variability in Transfer Criteria for Patients With Ruptured Abdominal Aortic Aneurysm, 2015). In such cases, transfer to a specialist center becomes part of the treatment pathway rather than an optional step. This can prolong the time to definitive repair, but it may also provide access to teams and resources that are not available at the referring hospital, including vascular surgeons, endovascular expertise, hybrid operating rooms, intensive care support, and more rapid blood product coordination (Chaikof et al., 2018; Wang et al., 2020).

The movement toward regionalization reflects the growing recognition that complex vascular emergencies often do better in centers with higher case volume and multidisciplinary experience (Kontopodis et al., 2021; Mell et al., 2017). rAAA is not simply a technical surgical problem; it is a coordinated emergency requiring rapid diagnosis, careful resuscitation, anesthesia expertise, blood bank readiness, and postoperative critical care (Chaikof et al., 2018; Scali et al., 2023). Specialist centers are more likely to have these elements in place and to operate within standardized pathways that reduce uncertainty and variation in care (Takei et al., 2023; Kontopodis et al., 2021). For that reason, regionalization is often intended to improve both the speed and the consistency of treatment, even though it may require the patient to travel farther (Mell et al., 2017).

At the same time, transfer is one of the most important sources of delay in the treatment pathway. Before a patient can be moved, the rupture must be recognized, the diagnosis must be communicated, the receiving center must accept the patient, and transport must be arranged (Variability in Transfer Criteria for Patients With Ruptured Abdominal Aortic Aneurysm, 2015; Mell et al., 2017). Each of these steps can introduce delay, especially if the initial presentation is atypical, if the diagnosis is uncertain, or if the referring hospital does not have a clear protocol for escalation (Mell et al., 2017; Scali et al., 2022). In practice, the transfer process is often slowed not by a single large problem but by several smaller delays that accumulate over time. These may include repeated assessment, waiting for imaging, uncertainty about whether transfer is safe, or slow communication between teams (Variability in Transfer Criteria for Patients With Ruptured Abdominal Aortic Aneurysm, 2015).

Transfer also raises important physiologic concerns. Patients with rAAA are extremely vulnerable during transport because their condition may worsen rapidly if blood pressure falls, bleeding increases, or perfusion deteriorates (Chaikof et al., 2018; Troisi et al., 2023). At the same time, overly aggressive resuscitation before definitive hemorrhage control may also be harmful because it can dislodge tamponade and intensify blood loss (Chaikof et al., 2018; Scali et al., 2023). This means that transfer is not just a logistical problem but also a clinical balancing act. The patient must be stable enough to move, but not so delayed by stabilization that the opportunity for definitive treatment is lost (Mell et al., 2017). The safest transfer strategy is therefore one that combines careful hemodynamic management with rapid coordination and clear communication between institutions (Chaikof et al., 2018; Mell et al., 2017).

The evidence suggests that transfer itself does not necessarily worsen outcomes if it is done efficiently and if the patient is appropriately selected for transport (Scali et al., 2022; The Effect of Patient Transfer on Outcomes After Rupture of an Abdominal Aortic Aneurysm, 2007). In some studies, transferred patients have had outcomes similar to or even better than those treated locally, likely because they ultimately receive care at specialist centers with greater expertise and broader treatment options (Scali et al., 2022; Kontopodis et al., 2021). However, this evidence must be interpreted carefully because transferred patients are often more stable than those who remain at the referring hospital (The Effect of Patient Transfer on Outcomes After Rupture of an Abdominal Aortic Aneurysm, 2007). In other words, transfer may appear beneficial partly because the patients who are transferred are the ones most likely to survive the journey. This selection effect makes it difficult to separate the effect of transfer from the effect of baseline stability (Scali et al., 2022).

Regionalization therefore should not be understood as a simple endorsement of moving all patients farther from home. Rather, it is a strategy for matching patients with the level of care they need (Kontopodis et al., 2021; Mell et al., 2017). In a well-organized system, the referring hospital's role is to recognize the rupture quickly, begin appropriate initial management, and activate a direct pathway to the most suitable center (Mell et al., 2017). The receiving hospital's role is to prepare for immediate intervention, whether that means open repair, EVAR, or another strategy based on anatomy and physiologic status (Wang et al., 2020; Chaikof et al., 2018). When these steps are coordinated effectively, transfer becomes an extension of treatment rather than a delay before treatment (Takei et al., 2023).

This section also has an important planning function in the review. It explains why treatment speed cannot be judged only by the number of minutes from arrival to incision. For many patients, the real issue is whether the care pathway is organized enough to move them rapidly to the correct environment for definitive repair (Kontopodis et al., 2021; Mell et al., 2017). Regionalization can therefore improve outcomes even if it adds transport time because a short delay in exchange for higher-quality care may be preferable to immediate but limited treatment in a hospital without the right resources (Scali et al., 2022; Wang et al., 2020). The clinical goal is not merely to avoid transfer, but to ensure that transfer is fast, purposeful, and tied to a clear treatment plan (Mell et al., 2017).

In summary, transfer and regionalization are best viewed as structural determinants of outcome in rAAA. They influence not only how quickly a patient reaches definitive repair, but also where that repair occurs, which team delivers it, and what treatment options are available (Kontopodis et al., 2021; Wang et al., 2020). This makes them essential to any serious discussion of timing in rAAA because they sit at the intersection of logistics, physiology, and specialist care (Chaikof et al., 2018; Mell et al., 2017). A review of treatment delay that does not address transfer and regionalization would miss one of the most important real-world reasons why definitive repair is delayed or expedited (Scali et al., 2022; Kontopodis et al., 2021).

7. Sources of Delay

Delays in the management of ruptured abdominal aortic aneurysm (rAAA) can occur at several points in the emergency pathway, beginning with the first clinical assessment and continuing through diagnosis, transfer, imaging, team mobilization, and preparation for repair (Mell et al., 2017; Chaikof et al., 2018). One of the earliest and most important causes is diagnostic uncertainty. Patients frequently present with abdominal pain, back pain, collapse, syncope, or other nonspecific symptoms, and the diagnosis may not be immediately recognized, especially when hypotension is absent or only mild (Abdominal Aortic Aneurysm: A Comprehensive Review, 2011; Troisi et al., 2023). In such circumstances, rAAA may initially be mistaken for renal colic, spinal pathology, gastrointestinal disease, or another non-vascular cause of acute pain (Chaikof et al., 2018; Troisi et al., 2023). This can delay vascular consultation, postpone definitive imaging or transfer, and lengthen the interval before operative planning begins (Mell et al., 2017; Variability in Transfer Criteria for Patients With Ruptured Abdominal Aortic Aneurysm, 2015).

Temporary hemodynamic stability can also contribute to delay. A patient who maintains a near-normal blood pressure at presentation may appear less urgent than a patient in overt shock, even though the rupture may still be evolving and severe (Scali et al., 2023; Troisi et al., 2023). This apparent stability may reduce the sense of urgency, encourage further observation, or lead clinicians to pursue additional diagnostic steps before activating the vascular pathway (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Mell et al., 2017). In rAAA, however, this can be particularly dangerous because clinical deterioration may occur rapidly and without much warning (Chaikof et al., 2018). The result is that a patient who initially seems relatively stable may lose the advantage of early intervention because treatment is started only after physiology worsens (Scali et al., 2023; Troisi et al., 2023).

Interhospital transfer is another major source of delay, particularly when patients first arrive at hospitals that do not have vascular surgery or emergency endovascular capability (Mell et al., 2017; Scali et al., 2022). Once rAAA is suspected or diagnosed, transfer to a specialist center should occur as quickly as possible, but in practice the process may involve repeated reassessment, communication between institutions, acceptance by the receiving team, ambulance coordination, and stabilization for transport (Variability in Transfer Criteria for Patients With Ruptured Abdominal Aortic Aneurysm, 2015; Mell et al., 2017). Delays may also arise when the referring hospital performs tests or repeated evaluations that do not alter the need for definitive treatment elsewhere (Scali et al., 2022). Although transfer is often necessary in order to access appropriate expertise and resources, inefficient referral pathways can significantly prolong the time to repair (The Effect of Patient Transfer on Outcomes After Rupture of an Abdominal Aortic Aneurysm, 2007; Scali et al., 2022).

Diagnostic imaging can also influence the overall timeline to intervention. In hemodynamically stable patients, computed tomography is commonly used to confirm rupture and determine anatomic suitability for endovascular repair (Chaikof et al., 2018; Wang et al., 2020). When integrated efficiently into the emergency pathway, CT can support rapid and appropriate decision-making (NICE, 2020; Wang et al., 2020). When it is poorly timed or unnecessarily repeated, however, imaging can become a major bottleneck that delays repair or transfer (Mell et al., 2017; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). Thus, the key issue is not whether imaging is performed, but whether it is used in a way that supports rather than delays definitive treatment. In unstable patients, this balance becomes even more important, since extensive imaging may be inappropriate if it postpones life-saving hemorrhage control (Chaikof et al., 2018; Troisi et al., 2023).

Further delay may result from organizational and logistical factors within the hospital itself. Access to an operating room or hybrid suite, mobilization of vascular and anesthesia teams, availability of blood products, and the need to decide between open repair and EVAR can all affect how quickly treatment begins (Wang et al., 2020; Takei et al., 2023). These issues are especially important in institutions without an established emergency vascular pathway, where each additional administrative or procedural step can prolong the route to definitive intervention (Takei et al., 2023; Mell et al., 2017). Even in well-equipped hospitals, lack of coordination between departments may create cumulative delay through fragmented communication and sequential rather than parallel preparation (Kontopodis et al., 2021; Takei et al., 2023).

Overall, delay in rAAA care is usually multifactorial rather than attributable to one single cause. Diagnostic uncertainty, transfer logistics, imaging decisions, staff mobilization, and institutional workflow can all contribute to a prolonged interval before repair (Mell et al., 2017; Kontopodis et al., 2021). Meaningful improvement therefore depends on optimizing the entire emergency pathway from first presentation to aortic control, rather than focusing on only one isolated bottleneck (Takei et al., 2023; Chaikof et al., 2018). This systems-based perspective is essential if time-to-intervention targets are to translate into practical improvements in patient care (Kontopodis et al., 2021; Mell et al., 2017).

8. System-Level Strategies to Improve Time to Intervention

Reducing time to intervention in ruptured abdominal aortic aneurysm (rAAA) requires improvement of the entire emergency treatment pathway rather than correction of a single isolated delay point (Mell et al., 2017; Chaikof et al., 2018). Because rAAA is a condition in which deterioration can occur rapidly, effective care depends on a system that can move the patient from suspicion to definitive repair with minimal avoidable delay (Troisi et al., 2023; Scali et al., 2023). Contemporary approaches therefore emphasize coordinated emergency pathways rather than reliance on individual clinical judgment alone (Takei et al., 2023; Mell et al., 2017). The aim is to ensure that diagnosis, triage, transfer, imaging, and operative preparation occur as parts of a single streamlined process rather than as separate and sequential tasks (Takei et al., 2023; Kontopodis et al., 2021).

One of the most important strategies is the centralization of care in specialist vascular centers (Kontopodis et al., 2021; Mell et al., 2017). Patients with suspected or confirmed rAAA should be transferred without unnecessary delay to hospitals capable of providing both open and endovascular repair, together with vascular anesthesia, blood product support, and critical care (Chaikof et al., 2018; NICE, 2020). Centralization can reduce variation in management and increase the likelihood that patients are treated by teams with appropriate technical expertise and institutional resources (Kontopodis et al., 2021). Its success, however, depends on the existence of efficient referral systems that allow rapid communication and direct movement into a specialist pathway (Mell et al., 2017; Scali et al., 2022).

Another key strategy is the use of standardized clinical protocols. Protocol-driven systems can support earlier recognition of rAAA, faster communication between emergency clinicians and vascular surgeons, prompt activation of operating room and anesthesia teams, and more efficient preparation for either transfer or immediate repair (Takei et al., 2023; Chaikof et al., 2018). These pathways are especially valuable because they reduce uncertainty and help ensure that critical steps occur in parallel rather than one after another (Takei et al., 2023; Mell et al., 2017). In a time-sensitive emergency, even modest reductions in repetition, hesitation, or administrative delay may have important clinical value (Kontopodis et al., 2021; Takei et al., 2023).

Diagnostic imaging must also be integrated intelligently into the treatment pathway. In hemodynamically stable patients, computed tomography remains essential for confirming rupture and determining anatomic suitability for EVAR (Chaikof et al., 2018; Wang et al., 2020). However, imaging should facilitate decision-making rather than become a source of delay (NICE, 2020; Mell et al., 2017). Contemporary systems increasingly support rapid CT in selected stable patients while discouraging unnecessary repeat imaging, prolonged local evaluation, or delays before referral (Mell et al., 2017; NICE, 2020). In unstable patients, imaging must be weighed carefully against the urgency of definitive hemorrhage control (Chaikof et al., 2018; Troisi et al., 2023).

The expanding role of EVAR has made system organization even more important. An endovascular-first strategy may reduce physiological stress in anatomically suitable patients, but it is only effective when supported by immediate imaging access, available devices, trained staff, and clear decision-making pathways (Powell et al., 2014; Wang et al., 2020). For this reason, some centers have adopted protocolized EVAR-based workflows or hybrid emergency room concepts designed to shorten the interval between diagnosis and definitive management (Takei et al., 2023; Wang et al., 2020). At the same time, open repair must remain readily available in patients for whom EVAR is not feasible or would introduce unnecessary delay (Reimerink et al., 2013; Chaikof et al., 2018). The value of the system lies not in promoting one technique over another, but in ensuring that the appropriate repair can be delivered rapidly (The IMPROVE Investigators, 2017; Wang et al., 2020).

Preoperative management also plays an important role in improving system efficiency. Emergency pathways often emphasize early large-bore intravenous access, controlled resuscitation, limited crystalloid use, rapid blood product availability, and blood pressure strategies intended to preserve perfusion without worsening hemorrhage (Chaikof et al., 2018; Troisi et al., 2023). These steps are not merely supportive; they help maintain the patient in a state in which definitive intervention remains possible while transfer or operative preparation is underway (Scali et al., 2023; Chaikof et al., 2018). Well-organized preoperative management therefore complements procedural speed rather than competing with it (Troisi et al., 2023).

Ultimately, the goal is not simply to achieve a predefined time threshold, but to create a vascular emergency system in which avoidable delay is consistently reduced (Kontopodis et al., 2021; Mell et al., 2017). Time-based quality indicators are most useful when they are employed to audit local performance, identify bottlenecks, improve protocols, and strengthen multidisciplinary coordination (Takei et al., 2023; Kontopodis et al., 2021). In this context, better outcomes are most likely to come from systems that are reliable, clearly structured, and capable of delivering definitive treatment without unnecessary interruption (The IMPROVE Investigators, 2017; Takei et al., 2023). This system-wide perspective is essential if improvements in time to intervention are to translate into meaningful gains in the care of patients with rAAA (Chaikof et al., 2018; Mell et al., 2017).

9. Discussion

The literature on ruptured abdominal aortic aneurysm (rAAA) consistently shows that time to intervention matters, but not in a simple or uniform way (Chaikof et al., 2018; Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). The basic biological rationale is clear: rupture causes ongoing hemorrhage, and every additional minute before definitive control increases the risk of shock, organ injury, and death (Chaikof et al., 2018; The Management of Ruptured Abdominal Aortic Aneurysms, 2023). At the same time, the available evidence suggests that a single timing threshold, including the commonly cited 90-minute benchmark, does not fully explain outcome variation across patients and institutions (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Kontopodis et al., 2021). This means that timing should be understood as one part of a broader clinical picture rather than as an isolated predictor (Kontopodis et al., 2021).

A major theme emerging from the literature is the difference between idealized pathway targets and real-world emergency care. In principle, rapid diagnosis and prompt intervention should improve outcomes (Chaikof et al., 2018; Mell et al., 2017). In practice, however, patients present with variable physiology, variable anatomy, and variable access to specialist vascular services (The Management of Ruptured Abdominal Aortic Aneurysms, 2023; Wang et al., 2020). Some patients require transfer, some require imaging before treatment, and some require stabilization before they can safely undergo repair (Mell et al., 2017; NICE, 2020). As a result, what appears to be “delay” in one case may actually represent necessary steps in another. The challenge for clinicians and health systems is to distinguish between avoidable and unavoidable delay (Kontopodis et al., 2021; Mell et al., 2017).

Another important issue is that outcome after rAAA is heavily influenced by baseline patient condition. A patient who arrives in profound shock may have a poor prognosis even if treatment is initiated quickly, while a more stable patient may survive despite a somewhat longer pathway to repair (The IMPROVE Investigators, 2017; Reimerink et al., 2013). This helps explain why timing alone does not always emerge as a strong independent predictor of mortality in adjusted analyses (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020). It also shows why studies of rAAA outcomes can appear contradictory: if the sickest patients are treated fastest but still die more often, then crude comparisons may underestimate the true value of rapid intervention (Kontopodis et al., 2021; Wang et al., 2020).

The discussion also needs to account for the changing role of EVAR and the growing centralization of vascular care. Modern treatment pathways are not built around one fixed operative strategy, but around the ability to choose the right repair quickly (Wang et al., 2020; Powell et al., 2014). In some patients, EVAR offers a faster and less physiologically stressful option; in others, open repair remains the best or only feasible treatment (Reimerink et al., 2013; Wang et al., 2020). That makes system organization crucial. A center that can rapidly determine anatomy, mobilize the correct team, and proceed with the most appropriate repair is more likely to improve outcomes than a center that simply aims for a short clock time without a clear treatment structure (Takei et al., 2023; Kontopodis et al., 2021).

Transfer and regionalization also complicate the interpretation of timing data. A hospital that refers patients quickly may appear slower on paper than a hospital that treats everyone locally, but the referred patient may ultimately receive better care in a specialist center (Mell et al., 2017; Impact of Interfacility Transfer of Ruptured Abdominal Aortic Aneurysm Patients, 2022). This means that time-to-intervention metrics should be interpreted alongside system design, case selection, and treatment capability (Kontopodis et al., 2021; Mell et al., 2017). The broader goal should not be to make every pathway identical, but to ensure that each patient reaches definitive care through the fastest safe route (Mell et al., 2017).

Overall, the evidence supports a balanced conclusion. The 90-minute benchmark is useful as a quality indicator and as a reminder of the urgency of rAAA, but it should not be treated as the sole measure of good care or as a rigid prognostic rule (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Mell et al., 2017). The real value of timing metrics lies in identifying weaknesses in diagnostic pathways, transfer systems, imaging workflows, and operating room readiness (Takei et al., 2023; Kontopodis et al., 2021). In that sense, time to intervention is best viewed as a marker of system performance and clinical coordination. For rAAA, the most meaningful improvements are likely to come from pathways that are both fast and well organized, rather than fast alone (Chaikof et al., 2018; Takei et al., 2023).

10. Conclusions

Ruptured abdominal aortic aneurysm remains one of the most time-critical emergencies in vascular surgery and continues to carry high morbidity and mortality despite advances in diagnosis, perioperative care, endovascular techniques, and regionalized service organization (Chaikof et al., 2018; The Management of Ruptured Abdominal Aortic Aneurysms, 2023). Current guideline-based care emphasizes not only definitive repair, but also the creation of emergency systems capable of moving patients rapidly from presentation to treatment in appropriately equipped vascular centers (Chaikof et al., 2018; Mell et al., 2017).

This review shows that time to intervention is a multidimensional concept rather than a single uniform measure. It may refer to door-to-intervention time, diagnosis-to-treatment time, transfer-related delay, or the interval required for imaging and operative preparation, all of which are influenced by hemodynamic status, anatomical suitability for EVAR, team availability, and access to specialist services (Variation in Hospital Door-to-Intervention Time for Ruptured AAAs and Its Association With Outcomes, 2020; Wang et al., 2020). For this reason, the commonly cited 90-minute benchmark is best understood as a quality target within a broader systems framework rather than as an isolated predictor of mortality in every individual patient (Mell et al., 2017; Kontopodis et al., 2021).

The available literature consistently supports the principle that avoidable delay should be minimized at every stage of the rAAA pathway, even if the precise effect size of delay differs across studies and clinical settings (Chaikof et al., 2018; Kontopodis et al., 2021). The most meaningful improvements in care are therefore likely to come from faster recognition, streamlined referral networks, efficient imaging pathways, early multidisciplinary activation, and immediate access to both open and endovascular repair in experienced centers (Takei et al., 2023; Mell et al., 2017).

Time-based performance measures remain valuable not because they determine prognosis on their own, but because they help reveal weaknesses in emergency organization and support continuous quality improvement in vascular services (Kontopodis et al., 2021; Takei et al., 2023). In that sense, time to intervention should be viewed both as a clinical priority and as a marker of how effectively a healthcare system delivers definitive care to patients with ruptured abdominal aortic aneurysm (Chaikof et al., 2018; Mell et al., 2017).

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