








# Comprehensive Review of Hybrid Emergency Room Systems: Benefits, Challenges, and Future Prospects

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## Abstract

Hybrid Emergency Room Systems (HERS) have emerged as a promising solution to address the challenges of timely and effective trauma management and acute care interventions. This review provides an in-depth exploration of HERS, its definition, historical development, advantages, disadvantages, successful implementations, economic considerations, and its potential role in the future of emergency care. HERS is designed to facilitate rapid assessment, diagnosis, and interventions by integrating various medical specialties, advanced imaging technologies, and interventional capabilities within the emergency care environment. Through comprehensive literature review and case studies, this article demonstrates how HERS has been utilized to improve patient outcomes in cases of trauma, cardiovascular emergencies, and other critical conditions. The advantages of HERS include enhanced coordination among medical specialties, streamlined communication, real-time imaging capabilities, and optimized resource utilization. However, challenges such as high costs, complexity, and accessibility limitations need to be considered. This review also discusses the economic implications of implementing HERS and presents a model-based cost-benefit analysis, underscores the importance of carefully planning and evaluating the implementation of HERS, considering its potential benefits and challenges. As HERS continues to evolve and gain recognition globally, its role in modern healthcare and emergency services is poised to become increasingly significant.

**Keywords:** HERS, hybrid emergency room, hybrid operating room

## INTRODUCTION TO HYBRID EMERGENCY ROOM SYSTEMS, ITS DEFINITION AND HISTORY

A significant portion of emergency room admissions comprise trauma patients. Trauma continues to be one of the most important causes of mortality in all age groups. Early intervention for these patients could be life-saving. Intervention in the early hours of admission is one of the most important factors affecting mortality. Rapid assessment bleeding control, imaging, and, if necessary, transfer to trauma centers are all part of trauma management. When these steps are distant from each other, it further limits the already restricted time we have.

The hybrid emergency room system (HERS) is formed to prevent time loss during trauma management. This system was initially launched to enable interventional radiologists to intervene at the patient's bedside using a computerized tomography (CT) table (1). Later it has been improved for intervention in many other diseases. The fundamental purpose of HERS is to provide interventions for patients in the room and to prevent time loss during their transfer to other units. Many potential benefits have been demonstrated with the implementation of hybrid emergency room systems (2). Most importantly, HERS helps rapid assessment, diagnosis, and management in trauma and acute cardiovascular events, where the golden hour is life-saving.



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With imaging methods readily available in the room, patients can be rapidly evaluated, and appropriate interventions can be initiated. HERS has been shown to improve patient outcomes and reduce morbidity and mortality (3).

In this article, we examine and evaluate the current status of hybrid emergency room systems. We will address the key components, benefits, challenges, and potential limitations of implementing these systems. By reviewing the existing literature and sharing insights from successful cases, we aim to comprehensively assess the impact and effectiveness of hybrid emergency room systems in enhancing accessibility, patient care, and overall emergency department management. Through our article, we hope to contribute to the ongoing debates regarding the future of emergency care and provide valuable insights to healthcare professionals considering the implementation of hybrid emergency room systems.

## METHODS

For this review, a comprehensive search was conducted using ClinicalKey/Elsevier, Scopus, Google Scholar, and local ULAKBIM databases. The search was conducted in English, and articles in other languages were not included. The keywords “HERS”, “Hybrid emergency room” and “HERS” were determined. In the initial search, 343 articles were identified. Through consecutive screening and analyzes it was found that among these articles, 59 specifically addressed the topic of the HERS. Further categorization revealed that 17 were case reports, 6 were reviews specifically focused on HERS, and 3 were reviews centered around hybrid operating rooms. This meticulously conducted methodology ensures that the review article is based on appropriate and valid literature selection, thereby facilitating a comprehensive exploration of the subject.

### History

HERS was developed in response to changing healthcare needs and advancements in medical technology. The concept and implementation have developed over time to provide more efficient and effective emergency services by managing patient loads and resource use. The history of hybrid healthcare systems can be traced back to the early 2000s when healthcare institutions began exploring alternative management approaches in emergency settings (2). According to Yamakawa et al. (1), one of the first hybrid room systems was implemented in August 2011 at Osaka General Medical Center in Japan. A computerized tomography (CT) unit with a movable table was added to this room, along with a monitor to display the

performed interventions. The key medical professional for this unit was an interventional radiologist. This setup allowed interventions to occur more swiftly than traditional trauma management. This system was named the hybrid emergency room system.

The driving force behind the development of hybrid emergency room systems was the need to address challenges such as overcrowded emergency departments, lengthy waiting times, and limited resources. Healthcare institutions have begun to recognize the significance of integrating urgent care centers, specialized clinics, and observation units within the emergency care environment. They began embracing this approach to provide comprehensive and personalized treatments based on the specific needs of patients. Advancements in medical technology, particularly in the field of imaging, have played a significant role in the development of hybrid emergency room systems. The integration of advanced imaging technologies such as CT scanners, ultrasound devices, and digital radiography into the emergency room environment has enabled rapid and accurate diagnostics. The capability to perform real-time imaging has provided crucial information for timely decision-making and targeted interventions by physicians (4).

Since their first introduction in Japan in 2011, the concept of hybrid emergency room systems has continued to gain global recognition and development. Different healthcare institutions and regions have progressed in adapting this model to their needs and resources. The positive outcomes and benefits provided by hybrid emergency room systems, such as reducing waiting times, increasing patient satisfaction, and optimizing resource allocation, have contributed to their widespread adoption (1). In particular, many trauma centers in Japan have turned to hybrid emergency room systems. According to Wada et al. (5), since its initial establishment, 21 trauma centers in Japan have implemented HERS.

### Coordination

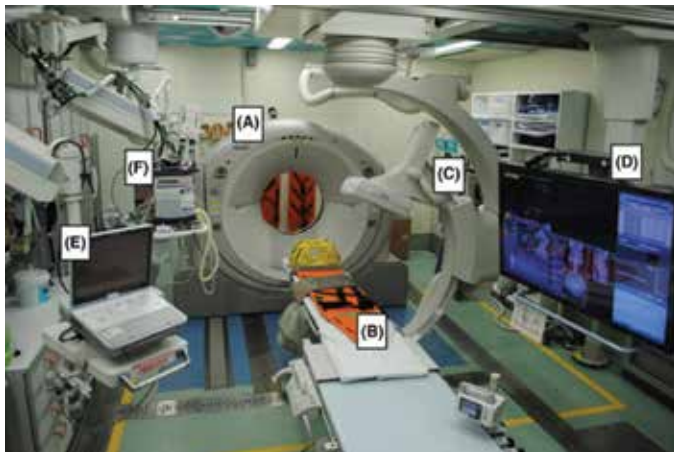
In a hybrid emergency service system, ensuring the effective coordination among various medical specialties is important. In this system, various medical disciplines work together to provide comprehensive patient care in the emergency service setting. This enables rapid and effective assessment of patients and implementation of crucial interventions. Experts from different specialties collaborate to evaluate patients' emergencies, make diagnoses, and develop treatment plans. In particular, for patients with multisystem traumas, branch specialists work together to determine the most suitable treatment (6).

HERS promotes effective communication and collaboration among the medical team. Experts assess patients' conditions together, share their experiences, and make decisions collaboratively. This approach results in faster diagnosis, more accurate treatment, and better patient outcomes. Advanced medical technology support coordination among medical specialties within HERS. Imaging technologies, laboratory tests, and other diagnostic tools provide essential information for patient evaluation and diagnosis. The effective use of these technologies enables experts to better understand patients' conditions and develop appropriate treatment plans. HERS encourages a comprehensive approach to patient care. Regular meetings and case discussions among different medical disciplines provide a platform for determining the best treatment strategies for patients' conditions. This process strengthens communication among the medical team and improves patient care (6).

### Hybrid Operating Rooms and Other Hybrid Systems

The term "hybrid" refers to the combination of two different things. In recent years, the implementation of hybrid systems in emergency services has increased, significantly altering the delivery of emergency care. A hybrid system combines advanced imaging technologies, interventional capabilities, and streamlined workflows to enhance the efficiency and effectiveness of emergency care. For HERS, this means that examination, imaging, and treatment can be performed together. Figure 1 shows one of the first HERS units set by Wada et al. (7).

The concept of a hybrid operating room was introduced earlier than the hybrid emergency service system in the early 2000s. The first hybrid operating room was established to manage



**Figure 1.** Shows a HERS unit set by Wada et al. (7), showing (A) CT scanner, (B) Intervention table, (C) Movable C-arm, (D) Monitor screen, (E) Ultrasound device, (F) Mechanical ventilator

complex cases requiring advanced imaging methods and surgical procedures (8). The hybrid operating room includes a CT scanner with interventional radiological capabilities within a traditional operating room setting. Today, the concept of a hybrid operating room has been further developed, incorporating techniques such as esuscitation with angioplasty, percutaneous techniques, and operative repair (9).

Therefore, why are hybrid emergency service and hybrid operating room systems important, even though traditional methods have a certain success rate? This question can be answered under several main headings:

1. Hybrid systems establish seamless communication and integration among multiple branches and resources. By bringing together the emergency, surgical, and radiology branches, hybrid environments promote collaborative work and advanced coordination. This coordination ensures that patients receive comprehensive and timely treatment tailored to their needs (10).
2. HERS and hybrid operating rooms are equipped with state-of-the-art CT scanners. MRI and angioplasty devices are also available. Having these imaging methods in the same area reduces diagnostic delays and allows for the implementation of effective intervention methods without wasting time (11).
3. Hybrid systems optimize emergency service management by transferring cases with lower urgency to monitoring units or acute medical centers, thus maximizing resource utilization (1).
4. Advanced imaging methods, a multidisciplinary approach, and patient-specific treatment methods yield better patient outcomes than traditional trauma management. Simultaneous imaging during intervention enables more precise methods and eliminates complications (12).

In summary, HERS and hybrid operating rooms enable comprehensive, multidisciplinary patient management, merging surgical interventions with advanced imaging methods. These models improve patient outcomes, enable minimally invasive procedures, enhance emergency care, optimize resource utilization, and ultimately contribute to the advancement of modern healthcare.

### Successful implementation of HERS

In a case presentation published by Wada et al. (13) in 2019, they described how a hybrid emergency room was used for a pediatric patient with a tracheobronchial injury. In this case, the HERS proved beneficial by facilitating the swift diagnosis of the injury, initiating veno-venous extracorporeal membrane oxygenation (VV ECMO) support, and subsequently performing

an emergency thoracotomy. This case highlights the potential of the HERS to ensure timely interventions in trauma cases and improve patient outcomes.

In another case presentation, Nishimura et al. (12) discussed the highly beneficial role of the HERS for treating a patient with a gunshot wound. Similar to what was demonstrated by Wada et al. (13), HERS enabled life-saving procedures such as CT scans and immediate surgical interventions to be performed at the same table without the need for patient transfer. This case also demonstrates how HERS has facilitated the precise evaluation of gunshot wounds, enabling surgeons to determine an optimal treatment strategy and quickly provide timely interventions. The use of HERS in the primary assessment stage has saved the patient's life by offering adequate and efficient treatment. This case underscores the significant advantage of HERS in providing rapid diagnosis and emergency surgical treatment for critical gunshot injuries.

Cardiac injuries have also demonstrated the utility of the hybrid emergency room system. In a case presentation published by Hara et al. (14) in 2022, they showcased how a hybrid emergency room (HER) equipped with advanced imaging technology and intervention capabilities provided rapid diagnosis and treatment for a patient without the need for patient relocation. In this case, the patient's unstable condition required immediate intervention, and HER provided rapid access to a CT scan for accurate diagnosis. In addition, HER allowed the safe and efficient implementation of venoarterial extracorporeal membrane oxygenation (VA-ECMO) for hemodynamic stabilization. Following patient stabilization in the hybrid emergency room, successful surgical treatment was performed in the operating room.

In a rare case series on HERS, Ito et al. (3) examined the impact of HERS on the management of bleeding due to pelvic fractures. The study was based on a retrospective analysis conducted from April 2015 to December 2018. This series included 96 patients; 72 patients were treated in a regular angio unit, called the non-HERS group, whereas 24 patients were treated in HERS. With advanced imaging and intervention capabilities, HERS has significantly increased the timely performance of angioembolization in pelvic fractures. This study emphasizes the importance of HERS in reducing morbidity and mortality due to pelvic fractures by reducing the time to intervention.

A case series by Miyazaki et al. (11) analyzed the use of venoarterial extracorporeal membrane oxygenation (VA-ECMO) in patients with severe pulmonary embolism requiring extracorporeal cardiopulmonary resuscitation in a hybrid emergency room. This article included nine patients who were treated between September 2014 and December 2017. Results

showed that with HERS, the use of VA-ECMO provided an 88.9% survival rate by reducing the time from diagnosis to intervention.

Umamura et al. (4), in a retrospective case series more comprehensive than its priors, analyzed 1,050 severe blunt trauma patients. Three hundred-sixty patients were treated in the traditional group, and 690 patients were treated in HERS. In the HERS group, the median age was significantly higher (57 vs. 49). The percentage of patients who received endovascular treatments was also higher in the HERS group (25.1% vs 17.2 %). The time from patient presentation to CT scan was 10 min in the HERS group, while this time was 26 min in the traditional group. Similarly, the time between arrival to emergency surgery or bleeding control was significantly lower in the HERS group. Twenty-eight-day mortality was significantly lower in the HERS group (12.7% vs 21.7%). This survival benefit was especially pronounced in patients with higher injury severity scores and patients with active bleeding seen on CT.

Ito et al. (3) demonstrated the importance of HERS in non-surgical emergencies during the Coronavirus disease-19 (COVID-19) pandemic. In patients with serious respiratory symptoms, Ito et al. (3) used HERS's CT capability before COVID-19 tests and provided early diagnosis. Using this method, they diagnosed and treated 1,500 patients in their hybrid emergency rooms (15).

### **Economic Cost of HERS**

Cost is an essential factor to consider when implementing a hybrid emergency service model. Because a considerable amount of capital investment will be required, it will be necessary to demonstrate first that this model is cost-effective in order to attract public or private funding.

In a study by Kinoshita et al. (16), a model-based cost-benefit analysis was performed. The analysis of patients with severe blunt trauma found that the hybrid emergency room provided a higher quality of life and better outcomes than the standard trauma process. However, the costs increased when considering the investment costs and maintenance requirements of the hybrid emergency room.

In the analysis, two critical criteria were used to evaluate the results of the two workflows: Quality-Adjusted Life Year (QALY) and Life Year (LY). QALY is a measure used to assess the impact of a treatment or health intervention on a patient's quality of life. The analysis found that the hybrid emergency room provided more QALY than the standard trauma process, meaning that patients had a higher quality of life.

LY, on the other hand, is a measure used to assess the effect of a treatment or intervention on a patient's lifespan. The analysis

determined that the use of the hybrid emergency room provided a longer LY than the standard trauma process, meaning that patients had a longer lifespan.

However, the costs of using the hybrid emergency room were also considered. Due to the investment costs and maintenance requirements of the hybrid emergency room, the costs of this workflow increased. The analysis concluded that the hybrid emergency room provided more QALY and LY, but these benefits were associated with increased costs. It was noted that the cost increased by \$32,522 for each QALY gained (13).

In another study by Balch et al. (8), the cost-effectiveness of hybrid emergency operating rooms was discussed. A comparison was made between a control group consisting of 106 patients before the installation of the hybrid operating room and 186 patients after the installation. When comparing costs, there was no significant difference in overall costs between the two groups (\$50,023 versus \$54,740,  $p=0.637$ ).

In conclusion, converting a standard trauma operating room into a hybrid operating room resulted in improvements in bleeding control, reduced transfusion requirements, and decreased incidence of postoperative pneumonia without a significant increase in costs. This study suggests that hybrid operating rooms can offer benefits in terms of patient outcomes without requiring significant additional costs (8).

### **Advantages and Disadvantages**

While so far in this review, we have shown significant advantages of HERS, there are also some disadvantages to consider. One of them is the high costs. The fact that hybrid emergency services are more modern and technology-based compared with traditional emergency services can increase investment costs, and hiring additional specialist physicians and staff can also increase operational costs. Moreover, additional resources may be needed to operate these services and train the staff, which can increase the overall cost of healthcare (16).

Another disadvantage is that in some regions, there may be limited infrastructure and resources allocated for hybrid emergency services. In particular, in rural areas or developing countries, the widespread adoption of hybrid emergency services may be challenging. In such cases, patients may face difficulty in accessing appropriate emergency healthcare when traditional emergency services are insufficient.

In the field of emergency medicine, newly established hybrid emergency systems represent a mixed approach that can be used alongside traditional emergency systems, offering various

advantages and disadvantages. Here are some advantages and disadvantages of hybrid emergency systems:

#### **Advantages:**

1. Integrated management: Hybrid emergency systems integrate different resources and expertise to manage various emergencies. This can improve coordination in emergency response and enhance response times (7).
2. Resource sharing: Hybrid systems can efficiently share various resources (humans, equipment, vehicles, and facilities) to respond to emergencies. This can optimize resource utilization and strengthen emergency response (3).
3. Flexibility and adaptability: Hybrid systems can provide a flexible structure to adapt to various emergency scenarios. They can be scaled according to change needs and support effective communication between different medical or emergency teams (12).

#### **Disadvantages:**

1. Complexity: Hybrid emergency systems can be complex because they require the integration of different resources and protocols. This complexity can pose challenges in terms of training, coordination, and management (17).
2. Communication challenges: Coordinating and communicating between different medical teams in hybrid systems can be challenging. Establishing effective communication channels among different systems is vital for their successful operation.
3. Team cohesion and training: Hybrid systems may require different medical and emergency teams to work together. Achieving cohesion and a harmonious working environment among teams may necessitate additional training and preparation.

Hybrid emergency systems should be carefully planned and implemented, considering their advantages and disadvantages. Proper training, communication, and

Management can contribute to the successful use of hybrid systems.

#### **Accessibility and the Future of Hybrid Systems**

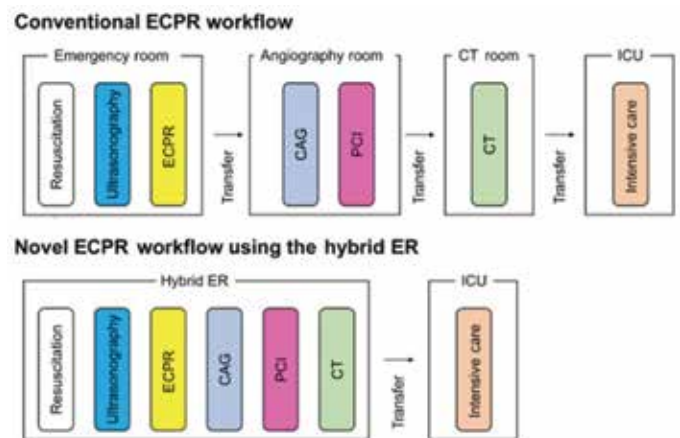
The hybrid emergency system is inherently complex in structure, encompassing hardware, technicians, nurses, and various specialized doctors. This system initially started with portable CT and evolved to include interventional procedures such as angiography and ECMO. Following the benefits provided by the hybrid system in terms of temporal and diagnostic processes, improvements were made to the treatment process, leading

to the establishment of hybrid operating rooms. However, the limitation of benefiting only a single patient and the decrease in system efficiency over time led to the development of the concept of a dual hybrid room. In a dual hybrid room, there are two separate chambers in which interventions can be performed on two patients simultaneously. These rooms are interconnected with a passage, enabling both teams to simultaneously conduct interventions and assist each other. Currently, hybrid systems are being implemented in various parts of the world, primarily in countries such as Japan, and the number of centers using these systems is increasing. In our country, there is currently no hybrid emergency system. The feasibility of implementing this system in our country, which comes with a high economic cost, is subject to debate. Factors such as technical and hardware infrastructure, quantity and quality of personnel, transportation, and cost need to be evaluated to assess the applicability of the hybrid system in suitable trauma centers. This dynamic system, with its advantages and disadvantages, continues to evolve, increasing its feasibility (7). The number of hybrid systems in other countries is gradually growing. With sufficient data and development, this system can also be used in our country.

## CONCLUSION

In conclusion, HERS is still under development worldwide. One of the most significant challenges in conventional emergency services is the delay in intervention for many life-threatening illnesses. The root cause of this delay lies in the transfer of patients to other units and the time it takes for consulting physicians to reach the emergency services for these patients. In traditional emergency services, procedures such as resuscitation, ECPR, and necessary ultrasound for diagnosing life-threatening illnesses are performed at the patient's bedside. Subsequently, the patient needs to be transported to the angiography unit or operating room. Then, there is a need to transfer the patient to the CT unit. All of these steps result in the loss of precious time critical for the patient's life. In conventional emergency settings, performing these procedures on specialized patients can lead to a significant loss of life. In HERS, however, after resuscitation, coronary angiography, embolization procedures, or embolectomy procedures, as well as CT and ultrasound for diagnosis, patients are transferred to the intensive care unit. Figure 2 shows the workflow difference between a traditional emergency room and HERS (7).

In our country, there is currently no hybrid emergency service. From our perspective, pioneering hybrid emergency services should be established in metropolitan cities. Considering the advantages, we believe that patient lives are far more important



**Figure 2.** From an article by Wada et al. (7) shows the difference in workflows between a conventional emergency room and HERS. In a traditional emergency room, a patient is transferred at least 2 times during diagnosis and treatment, resulting in time losses during management. However, in HERS, patients do not need to be transferred, as diagnosis and treatment can be done in the same room

than costs. However, we have some reservations. One of these concerns is the traffic issue in Turkish metropolises. Transporting patients to established hybrid emergency services could take a long time. Therefore, in these Turkish metropolises, a few hospitals should be selected to use hybrid emergency services. Our concern is the employment of physicians in these established services. In our country, which is composed of seven regions, this issue could be addressed by employing interventional radiologists in nearby cities within specific regions. In this way, our concern about physician employment can be overcome.

Multitrauma patients, patients undergoing resuscitation, acute myocardial infarction patients, pelvic traumas, patients with aortic aneurysms or dissections, patients requiring ECMO, and especially hypotensive pulmonary embolism patients requiring embolectomy would be managed much more effectively and efficiently in hybrid emergency services than in conventional emergency services. Therefore, we think that a hybrid emergency service should be established in our country as soon as possible.

## Ethics

**Peer-review:** Internally peer reviewed.

## Authorship Contributions

Concept: M.N.A., B.K., B.Ö., A.K., Design: M.N.A., B.Ö., Z.A., Analysis or Interpretation: B.U., A.D., İ.G., A.K., Literature Search: B.K., A.D., İ.G., Writing: B.K., M.N.A., A.D., B.Ö., A.K.

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