

The Impact of Time to Definitive Care on Patient Outcomes: Examining 'Golden Hour' Compliance and Its Effects on Mortality and Morbidity

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Abstract

Background: The "golden hour" principle emphasizes the importance of providing definitive care within the first 60 minutes following trauma to improve outcomes. This study aimed to evaluate golden hour compliance and its impact on mortality and morbidity among trauma patients in a tertiary care hospital.

Methods: A retrospective cohort study was conducted on **320 trauma patients** over a 12-month period. Data on pre-hospital delays, in-hospital interventions, and patient outcomes were analyzed. Logistic regression was used to identify predictors of mortality.

Results: Golden hour compliance was achieved in **65.6%** of patients. Non-compliance was significantly associated with higher mortality (**31.8% vs. 7.1%, $p < 0.001$**), increased ICU admissions (**68.2% vs. 38.1%, $p < 0.001$**), longer hospital stays, and greater ventilator dependence. Key factors contributing to delays included extended pre-hospital times (59.1%) and trauma team activation delays (18.2%). Logistic regression identified golden hour non-compliance as the strongest predictor of mortality (OR: **3.5, 95% CI: 2.1–6.0, $p < 0.001$**).

Conclusion: Golden hour non-compliance significantly worsens trauma outcomes. Addressing pre-hospital delays and optimizing in-hospital trauma systems are critical to improving patient survival and recovery.

Keywords: Golden hour, Trauma care, Definitive care, Mortality, Pre-hospital delays, Tertiary hospital, Injury severity

Introduction

Trauma remains a major global health challenge and one of the leading causes of mortality and morbidity, particularly among young and productive populations. The "golden hour" concept, introduced by R. Adams Cowley in the 1970s, highlights the critical importance of delivering definitive medical care within the first 60 minutes after injury to reduce the risk of death and long-term complications (Lerner & Moscatti, 2001). This principle has become a cornerstone in modern trauma care systems, as it underscores the need for rapid interventions to mitigate the effects of severe hemorrhage, traumatic brain injury (TBI), and shock (Rogers et al., 2015).

Numerous studies have emphasized the role of pre-hospital and in-hospital delays in influencing trauma outcomes. For instance, a systematic review by Harmsen et al. (2015) demonstrated that prolonged pre-hospital time is associated with higher mortality, particularly in patients with critical injuries requiring urgent surgical intervention. Similarly, Newgard et al. (2010) analyzed emergency medical services (EMS) intervals and found that shorter response times significantly improved survival rates among severely injured patients, particularly those experiencing hemorrhagic shock or TBI.

In addition to time constraints, factors such as injury severity, pre-hospital care quality, and transport mode can further impact outcomes. Alarhayem et al. (2016) observed that for patients with torso hemorrhage, the majority of deaths occurred before hospital arrival, underscoring the need for rapid identification and management of life-threatening injuries. Meanwhile, advances in air medical transport and pre-hospital interventions, such as fluid resuscitation and early airway management, have contributed to improved compliance with golden hour standards in resource-adequate settings (Tien et al., 2011).

Despite its widespread adoption, the golden hour principle has faced scrutiny in recent years. Newgard et al. (2015) reported that while rapid time-to-treatment is critical for some patient groups, other factors, such as physiological stability and injury patterns, may play a more significant role in determining outcomes. However, evidence continues to support the association between timely definitive care and improved survival in trauma systems with integrated pre-hospital and in-hospital care pathways (Claridge et al., 1999; Rogers et al., 2015).

This study aims to evaluate compliance with the golden hour principle in a tertiary hospital setting and assess its impact on mortality and morbidity among trauma patients. By identifying delays in care delivery and understanding their root causes, the findings will inform improvements in trauma management systems, ultimately enhancing patient outcomes.

Literature Review

1. The Golden Hour Concept

The golden hour, coined by R. Adams Cowley in the 1970s, refers to the critical first 60 minutes following traumatic injury, during which prompt medical intervention significantly reduces mortality and morbidity (Lerner & Moscatti, 2001). This concept has become a cornerstone in trauma care protocols, particularly in integrated trauma systems where rapid pre-hospital and in-hospital interventions play a pivotal role. The rationale behind the golden hour lies in preventing irreversible physiological derangements caused by hemorrhage, hypoxia, and traumatic brain injury (Rogers et al., 2015).

The early recognition and adherence to the golden hour principle have been shown to improve survival rates. A study conducted by Claridge et al. (1999) demonstrated that timely interventions during the initial hour, combined with effective detection of occult hypoperfusion within the first 24 hours, significantly improved trauma outcomes. However, despite its theoretical importance, challenges remain in achieving consistent compliance, particularly in resource-limited settings or rural areas with extended transport times.

2. Pre-Hospital Interventions and Transport Times

Pre-hospital care is the initial phase of trauma management where time-sensitive interventions can directly influence patient outcomes. Harmsen et al. (2015) performed a systematic review of pre-hospital transport

times and concluded that prolonged pre-hospital delays were strongly associated with increased mortality, particularly for patients requiring urgent surgical interventions. Similarly, Alarhayem et al. (2016) observed that for torso hemorrhage patients, mortality often occurred before hospital arrival, emphasizing the need for rapid pre-hospital interventions, including fluid resuscitation and early control of bleeding.

Transport modalities play a significant role in ensuring adherence to the golden hour. Air medical transport, often used for severely injured patients in remote areas, has been associated with reduced transport times and improved outcomes. Tien et al. (2011) reported that air transport minimized time-to-treatment for acute subdural hematomas, resulting in lower mortality. However, the benefits of air versus ground transport may vary depending on injury severity, distance, and availability of advanced pre-hospital care.

Despite these advancements, Newgard et al. (2015) found that pre-hospital delays were sometimes unavoidable due to challenges such as prolonged extrication, scene stabilization, and geographic constraints. Their findings suggest that while the golden hour is critical, patient factors like physiological status and injury severity can sometimes outweigh time delays in determining outcomes.

3. Time to Definitive Care and In-Hospital Management

Definitive care, such as surgical interventions, blood transfusions, and intensive monitoring, is essential for trauma survival. The interval between injury and definitive care has been strongly linked to patient outcomes. A study by Rogers et al. (2015) highlighted that delays in definitive care, particularly for hemorrhage control and TBI management, significantly increased mortality risks. For example, patients requiring emergency laparotomy for intra-abdominal bleeding experienced improved survival when definitive care was initiated within the golden hour.

In contrast, Newgard et al. (2010) questioned the universal applicability of the golden hour principle, arguing that while rapid time-to-care is essential for certain trauma subgroups, other variables, such as injury physiology, may have a more significant impact. They observed that patients with severe shock or head injuries benefited most from early interventions, whereas those with isolated injuries had more flexible time windows.

The importance of in-hospital readiness to receive trauma patients cannot be overstated. A retrospective analysis by Tien et al. (2011) demonstrated that delays in surgical readiness, even after timely pre-hospital transport, negated the benefits of the golden hour. Effective trauma team activation, operating room preparedness, and early resuscitation strategies were identified as critical components of successful in-hospital trauma management.

4. Re-Evaluating the Golden Hour in Modern Trauma Care

While the golden hour remains a guiding principle, its universal applicability has been debated. Recent studies suggest that the golden hour may not equally apply to all trauma patients. For instance, Alarhayem et al. (2016) found that in cases of severe torso hemorrhage, mortality could occur well before the golden hour, indicating that even shorter response times are necessary for such injuries. Conversely, patients with less severe injuries may tolerate longer delays without significant outcome deterioration.

Additionally, advances in pre-hospital care, such as point-of-care ultrasound, early administration of tranexamic acid (TXA), and telemedicine, have expanded the scope of interventions that can be delivered

before hospital arrival. These advancements challenge the traditional golden hour concept by suggesting that early pre-hospital interventions can extend the survival window for critically injured patients (Harmsen et al., 2015).

Nonetheless, studies continue to demonstrate the benefits of timely care in integrated trauma systems. Rogers et al. (2015) concluded that while the golden hour may not be a rigid rule, its principles remain relevant in ensuring rapid recognition, stabilization, and definitive care for severely injured patients.

5. Challenges and Gaps in Golden Hour Compliance

Achieving consistent compliance with the golden hour principle remains challenging due to several factors:

1. **Geographic Barriers:** Rural or remote areas face delays in transport, especially where air medical services are unavailable (Newgard et al., 2015).
2. **Systemic Delays:** Delays in trauma activation, operating room readiness, or resource limitations can hinder timely care (Tien et al., 2011).
3. **Injury Severity and Complexity:** Patients with multiple injuries or comorbidities may require prolonged stabilization, which can delay transport (Alarhayem et al., 2016).

Addressing these challenges requires a multi-faceted approach, including strengthening EMS systems, optimizing pre-hospital care protocols, and improving in-hospital trauma management readiness.

Conclusion of Literature Review

The golden hour remains a critical period in trauma care, with strong evidence supporting its association with reduced mortality and morbidity. However, recent studies have highlighted the need for a nuanced understanding of its applicability based on injury severity, pre-hospital interventions, and systemic factors. By identifying barriers to golden hour compliance and addressing delays in care delivery, trauma systems can optimize outcomes for critically injured patients.

Methodology

Study Design

This study utilized a **retrospective cohort design** to analyze the impact of time to definitive care on mortality and morbidity among trauma patients presenting to the Emergency Department (ED) of a tertiary care hospital. The study was conducted over a **12-month period**, utilizing existing patient records from the hospital's trauma registry.

Study Setting

The study was conducted at Tertiary Hospital, a **Level I trauma center** that receives a high volume of trauma cases. The facility is equipped with a specialized trauma team, 24/7 emergency surgical capabilities, and access to advanced diagnostics and critical care services.

Study Population

The study included all trauma patients who met the following inclusion and exclusion criteria:

Inclusion Criteria:

1. Patients aged 18 years and older.
2. Patients with moderate to severe trauma (Injury Severity Score (ISS) \geq 9).
3. Patients transported to the tertiary hospital within 6 hours of injury.
4. Patients with complete medical and pre-hospital records.

Exclusion Criteria:

1. Patients with non-trauma-related injuries (e.g., medical emergencies).
2. Patients declared dead on arrival (DOA).
3. Patients transferred from another hospital where definitive care was already initiated.

Data Collection

Data were extracted from the hospital's trauma registry, pre-hospital records, and electronic medical records (EMRs). The following parameters were collected:

1. **Demographic Data:** Age, gender, comorbidities.
2. **Pre-Hospital Data:**
 - Time of injury.
 - Pre-hospital response time (time from emergency call to arrival at the scene).
 - Transport time (time from scene to hospital).
 - Mode of transport (ground ambulance, air medical transport).
 - Interventions performed at the scene (e.g., airway management, bleeding control).
3. **In-Hospital Data:**
 - Time of ED arrival.
 - Time to definitive care (e.g., time to surgery, imaging, blood transfusion).
 - ISS (Injury Severity Score) and Revised Trauma Score (RTS).
 - In-hospital interventions (e.g., surgical procedures, ICU admission).
4. **Outcomes:**
 - Mortality (in-hospital and 30-day mortality).
 - Morbidity (length of hospital stay, ICU admission, ventilator days, discharge disposition).

Operational Definitions

- **Golden Hour Compliance:** Defined as the delivery of definitive care (e.g., surgery, hemorrhage control) within **60 minutes** of patient arrival to the hospital.
- **Definitive Care:** The first major intervention aimed at stabilizing the patient, such as surgical intervention, blood transfusion, or emergency procedures.
- **Morbidity Indicators:** Length of stay > 7 days, ICU admission > 72 hours, and ventilator support > 48 hours.

Data Analysis

The collected data were entered into **SPSS version 25** for statistical analysis.

1. Descriptive Statistics:

- Frequencies and percentages for categorical variables (e.g., transport mode, golden hour compliance).
- Mean and standard deviation for continuous variables (e.g., response time, ISS).

2. Inferential Statistics:

- **Chi-Square Test:** To assess the association between golden hour compliance and mortality/morbidity.
- **Independent T-Test:** To compare means of continuous variables (e.g., time delays) between groups.
- **Logistic Regression:** To identify predictors of mortality and golden hour compliance, adjusting for confounders like ISS, age, and comorbidities.

3. Outcome Measures:

- **Primary Outcome:** Mortality rates (in-hospital and 30-day).
- **Secondary Outcomes:** Morbidity indicators such as ICU length of stay and ventilator days.

Results Presentation

Results were presented using tables, graphs, and charts to highlight:

- Golden hour compliance rates.
- Association of compliance with mortality and morbidity.
- Factors contributing to delays in definitive care, such as transport times and pre-hospital interventions.

Ethical Considerations

The study was conducted in compliance with the Declaration of Helsinki and approved by the **ethics committee**. Patient anonymity was ensured, and no identifiable information was included in the analysis. Informed consent was waived due to the retrospective nature of the study.

Conclusion of Methodology

This methodology provides a comprehensive framework to assess the relationship between golden hour compliance and trauma patient outcomes. By evaluating pre-hospital delays, in-hospital interventions, and their impact on mortality and morbidity, the findings offer valuable insights for improving trauma systems and patient care delivery.

Findings

The findings of the study are presented in three main sections: (1) Patient demographics, (2) Golden hour compliance and delays, and (3) Impact of golden hour compliance on mortality and morbidity. Statistical significance was set at $p < 0.05$.

1. Patient Demographics

A total of **320 trauma patients** were included in the study. Table 1 shows the demographic details, injury characteristics, and pre-hospital transport mode.

Table 1: Demographic and Clinical Characteristics of Trauma Patients

Variable	Total (N = 320)	Golden Hour Compliant (N = 210)	Non-Compliant (N = 110)	p-value
Age (Mean ± SD)	35.8 ± 12.4	33.4 ± 10.7	39.5 ± 11.3	<0.001
Gender (Male)	240 (75%)	160 (76.2%)	80 (72.7%)	0.56
Injury Severity Score (ISS)	18.4 ± 7.6	17.2 ± 6.9	20.5 ± 8.3	0.02
Transport Mode				
Ground Ambulance	210 (65.6%)	145 (69%)	65 (59.1%)	0.04
Air Medical Transport	110 (34.4%)	65 (31%)	45 (40.9%)	

Key Findings:

- The mean age of the patients was **35.8 years**, with the golden hour non-compliant group being significantly older ($p < 0.001$).
- **ISS scores** were higher in the non-compliant group (20.5 vs. 17.2; $p = 0.02$), indicating more severe injuries.
- Air transport was utilized more often in the non-compliant group, suggesting longer pre-hospital response times for rural or distant cases.

2. Golden Hour Compliance and Delays

Golden hour compliance was achieved in **210 patients (65.6%)**, while **110 patients (34.4%)** experienced delays. The factors contributing to delays are summarized in Table 2.

Table 2: Factors Contributing to Delays in Definitive Care

Delay Factor	Frequency (N = 110)	Percentage (%)
Extended Pre-Hospital Time (>30 min)	65	59.1%
Delays in Trauma Team Activation	20	18.2%
Imaging/Diagnostics Delays	15	13.6%
Operating Room Unavailability	10	9.1%

Key Findings:

- **Pre-hospital delays** were the most common factor, observed in **59.1%** of non-compliant patients.
- **Trauma team activation delays** contributed to **18.2%** of the cases.
- In-hospital delays such as imaging or operating room unavailability accounted for the remaining **22.7%**.

3. Impact of Golden Hour Compliance on Outcomes

Table 3 illustrates the comparison of mortality and morbidity outcomes between golden hour compliant and non-compliant groups.

Table 3: Outcomes Based on Golden Hour Compliance

Outcome	Golden Hour Compliant (N = 210)	Non-Compliant (N = 110)	p-value
Mortality	15 (7.1%)	35 (31.8%)	<0.001
ICU Admission	80 (38.1%)	75 (68.2%)	<0.001
Length of Stay (Days, Mean)	6.8 ± 2.1	11.5 ± 3.7	<0.001
Ventilator Support (>48 hrs)	25 (11.9%)	50 (45.5%)	<0.001

Key Findings:

- **Mortality** was significantly higher in the non-compliant group (**31.8%** vs. **7.1%**; $p < 0.001$).
- Patients in the non-compliant group had **higher ICU admission rates** (68.2% vs. 38.1%; $p < 0.001$).
- The **mean length of hospital stay** was significantly longer in non-compliant patients (11.5 vs. 6.8 days; $p < 0.001$).
- **Ventilator support** lasting more than 48 hours was observed in **45.5%** of the non-compliant group compared to **11.9%** in the compliant group.

4. Logistic Regression Analysis

A multivariate logistic regression model was conducted to identify predictors of mortality. Table 4 shows the adjusted odds ratios (OR) for significant predictors.

Table 4: Predictors of Mortality in Trauma Patients

Variable	Adjusted OR (95% CI)	p-value
Golden Hour Non-Compliance	3.5 (2.1–6.0)	<0.001
Injury Severity Score (ISS > 20)	2.8 (1.5–5.2)	0.001
Extended Pre-Hospital Time	2.2 (1.3–3.9)	0.004
Age > 40 Years	1.9 (1.1–3.4)	0.02

Key Findings:

- **Golden hour non-compliance** was the strongest predictor of mortality, with an adjusted odds ratio of **3.5** (95% CI: 2.1–6.0; $p < 0.001$).
- High **ISS scores (>20)** and extended pre-hospital times were also significant predictors of mortality.

Summary of Findings

1. Golden hour compliance was achieved in **65.6%** of patients.
2. Non-compliance was associated with:
 - Extended pre-hospital times (59.1%).

- Delays in trauma team activation and in-hospital care.
- 3. Non-compliance significantly increased mortality (**31.8% vs. 7.1%**) and morbidity (longer ICU stays, ventilator support, and hospital stay).
- 4. Logistic regression analysis confirmed golden hour non-compliance as an independent predictor of mortality.

Discussion

The current study examined the impact of golden hour compliance on patient outcomes in a tertiary care hospital and identified factors contributing to delays in definitive trauma care. The findings reaffirm the importance of timely interventions, as non-compliance with the golden hour was associated with significantly higher mortality, longer ICU stays, extended hospital admissions, and increased ventilator dependency.

1. Golden Hour Compliance and Patient Outcomes

The results demonstrated that only **65.6% of patients** received definitive care within the golden hour. Non-compliance was associated with a **4.5-fold higher mortality rate** (31.8% vs. 7.1%), longer ICU admissions, and extended hospital stays. These findings align with previous studies, including those by Harmsen et al. (2015) and Tien et al. (2011), which emphasized that delays in initiating critical interventions (e.g., hemorrhage control, airway stabilization) increase the risk of death and long-term complications.

The importance of the golden hour lies in mitigating secondary physiological insults, such as hypoxia and hypoperfusion, which exacerbate outcomes in severely injured patients. This is particularly critical in cases of traumatic brain injury (TBI) and hemorrhagic shock, where delays in definitive care significantly reduce survival chances (Alarhayem et al., 2016).

2. Factors Contributing to Delays in Definitive Care

The most common contributor to golden hour non-compliance was **extended pre-hospital time**, accounting for **59.1%** of delays. This finding reflects systemic challenges in trauma care delivery, particularly in regions with long transport distances, poor infrastructure, or delayed pre-hospital response times. Newgard et al. (2015) similarly reported that prolonged extrication times, scene stabilization, and geographic factors significantly contribute to pre-hospital delays, especially in rural or remote areas.

In addition to pre-hospital factors, **in-hospital delays**, such as trauma team activation issues and operating room unavailability, contributed to non-compliance. Despite arriving at the ED within the golden hour, **18.2% of patients** experienced delays due to systemic inefficiencies. These findings highlight the need for improved hospital readiness, streamlined trauma protocols, and real-time communication between pre-hospital and in-hospital teams. Tien et al. (2011) emphasized that delays in surgical readiness could negate the benefits of rapid transport and early pre-hospital interventions.

3. Predictors of Mortality

Logistic regression analysis identified **golden hour non-compliance** as the strongest independent predictor of mortality (OR: 3.5; 95% CI: 2.1–6.0). Other significant predictors included **high Injury Severity Scores (ISS > 20)**, extended pre-hospital times, and advanced age (>40 years). These findings corroborate existing

literature, such as the study by Rogers et al. (2015), which demonstrated that both injury severity and delays in care play critical roles in determining patient outcomes.

Interestingly, air transport was more frequently utilized in non-compliant cases, suggesting that patients transported from distant or rural areas often experienced prolonged pre-hospital times. While air medical transport reduces transport time compared to ground ambulances, logistical and operational challenges may still delay definitive care in some cases.

4. Revisiting the Golden Hour Concept

While the golden hour remains a cornerstone of trauma care, some studies have questioned its universal applicability. Newgard et al. (2010) suggested that physiological variables, such as injury severity and hemodynamic instability, may have a greater influence on outcomes than strict adherence to the 60-minute threshold. Similarly, Alarhayem et al. (2016) demonstrated that mortality from hemorrhagic torso injuries could occur well before the golden hour elapses, highlighting the need for ultra-rapid pre-hospital interventions.

Nevertheless, the findings of the current study reinforce the continued relevance of the golden hour in modern trauma care. By identifying delays in both pre-hospital and in-hospital phases, this study highlights the importance of a well-coordinated trauma system that integrates early recognition, pre-hospital stabilization, and expedited definitive care.

5. Implications for Practice

To improve golden hour compliance and patient outcomes, the following strategies should be considered:

1. Enhancing Pre-Hospital Care:

- Reduce pre-hospital response and transport times through strategic placement of EMS teams and air medical services.
- Train paramedics to initiate critical interventions such as hemorrhage control, fluid resuscitation, and airway management.

2. Optimizing In-Hospital Trauma Systems:

- Streamline trauma team activation protocols to ensure readiness before patient arrival.
- Improve operating room preparedness and reduce delays in imaging and diagnostics.

3. Leveraging Technology:

- Use telemedicine to support pre-hospital teams with real-time decision-making.
- Implement tracking systems for patient transport and trauma team readiness.

6. Study Strengths and Limitations

The strengths of this study include its large sample size, focus on a tertiary hospital setting, and detailed analysis of factors contributing to delays in care. However, the study also has limitations:

- **Retrospective Design:** Reliance on existing records may have led to incomplete or missing data.
- **Single-Center Study:** The findings may not be generalizable to hospitals with different trauma care capacities.

- **Confounding Variables:** Despite adjustments, unmeasured factors such as comorbidities or pre-existing conditions may have influenced outcomes.

Conclusion

This study reaffirms the critical importance of golden hour compliance in reducing mortality and morbidity among trauma patients. Delays in pre-hospital and in-hospital care remain significant challenges, particularly in patients with severe injuries or geographic barriers to timely transport. Addressing these delays through improved EMS systems, streamlined trauma protocols, and enhanced hospital readiness will be essential for optimizing trauma care and patient outcomes.

Future Recommendations

1. Conduct prospective multi-center studies to further evaluate golden hour compliance and its effects on outcomes.
2. Investigate the impact of pre-hospital interventions, such as early administration of tranexamic acid (TXA), on extending the survival window.
3. Develop region-specific strategies to address pre-hospital delays in rural and remote settings.

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