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# Using Serial Hemoglobin Levels to Detect Occult Blood Loss in the Early Evaluation of Blunt Trauma Patients

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**Abstract**

**Objective:** Serial hemoglobin measurement (ΔHgb) is intended to aid in the early identification of blunt trauma patients who have significant blood loss requiring intervention. However, the utility of ΔHgb has yet to be rigorously studied. We sought to determine if ΔHgb is a reliable diagnostic tool in assessing blood loss in blunt trauma patients.

**Methods:** We enrolled consecutive blunt trauma patients 18 years of age and older, presenting to a level I trauma center. We measured two hemoglobin levels spaced five minutes apart and calculated the difference, ΔHgb, for each patient. We also recorded whether each patient required any of the following interventions to treat their injuries; 1 - Operation or procedure to control hemorrhage, 2 - radiographic embolization, 3 - administration of blood and blood products, 4 - administration of three or more liters of IV fluids, 5 - exsanguination. Our primary outcome was the area under the receiver-operator curve (ROC).

**Results:** We enrolled 251 patients, including 192 males and 59 females with a mean age of 40. Interventions occurred in 56 patients and were withheld in 195. The median ΔHgb was -0.1 gm/dl (Interquartile range: -0.5 gm/dl to 0.1 gm/dl) for patients requiring intervention, and 0.0 gm/dl (Interquartile range: -0.6 gm/dl to 0.3 gm/dl) for patients not requiring intervention. We found the area under the ROC to be 0.53 (95% Confidence interval: 0.44 – 0.62).

**Conclusions:** Our results indicated that ΔHgb does not reliably distinguish between blunt trauma patients who require intervention, and those who do not.

## Introduction

Traumatic hemorrhage results in the loss of whole blood, including plasma and red blood cells. The resultant loss of intravascular volume triggers shifts of interstitial and intracellular fluid that act to restore overall intravascular volume, but do not restore erythrocyte and hemoglobin losses and result in a dilution of the intravascular concentration of red blood cells and hemoglobin. This conceptual framework provides the rational for using measurements of hematocrit and hemoglobin concentration to assess blood loss in blunt trauma patients. However, baseline hematocrit and hemoglobin levels are affected by many factors not associated with bleeding such as age, gender, weight, volume of distribution, fluid status, and underlying conditions such as anemia.[1] As a result, single measurements have limited utility in the early assessment of blunt trauma patients.[2,3]

Because the performance of single hemoglobin and hematocrit assessments is unreliable, serial measures have been suggested as a means of identifying patients who have decreasing values that might signify ongoing hemorrhage, and the use of serial hematocrit or serial hemoglobin measurements is now part of the routine evaluation of trauma patients at many institutions across the United States.[4] However, recent studies on the utility of serial measurements have produced inconclusive results.[1,4,5] These differing conclusions reflect differences in methodology, study populations, and the time frame of the serial evaluations.

The goal of our study was to prospectively examine the performance of serial hemoglobin (ΔHgb) measurements in the early resuscitation of blunt trauma patients at five-minute intervals, and assess the ability of ΔHgb to identify patients who require emergent intervention. The five-minute time interval was specifically chosen because of its relevance to typical trauma resuscitations and the ability of these measurements to identify patients and influence care in the early stages of trauma resuscitations where evaluations and decisions are made in relatively short time intervals. Furthermore, there is no current literature to illuminate the utility of serial hemoglobin measurements in this time frame.

We specifically wanted to examine the receiver-operator curve (ROC) to assess the discriminating capability of serial measurements.

## Methods

### Study design and setting

We conducted an observational study that enrolled consecutive blunt trauma patients 18 years of age and older, presenting to a level I trauma center. We excluded patients who were younger than 18 years of age, pregnant, were primarily burn victims, sustained penetrating trauma, were transferred from another hospital, or received interventions prior to the second hemoglobin measurement. The study involved recording the first two hemoglobin levels that were routinely assessed at five-minute intervals on all patients presenting to our institution for blunt trauma evaluations. Nursing personnel provided hemoglobin measurements to treating clinicians as part of normal practice, but study personnel did not inform the treating clinicians of any measurements or changes in hemoglobin levels, and the study did not interfere or otherwise alter the care of any patients. The study was reviewed by the UCLA Institutional Review Board and approval was granted under a waiver of informed consent.

**Measurements and outcomes**

We calculated the difference, ΔHgb, for the two measured hemoglobin levels for each patient. We also recorded whether each patient required any of the following interventions to treat their injuries; 1 - Operation or procedure to control hemorrhage, 2 - radiographic embolization, 3 - administration of blood and blood products, 4 - administration of three or more liters of IV fluids, 5 - exsanguination. We counted only interventions that took place within the first 24-hours of the patient's arrival to the resuscitation suite. We documented interventions that occurred in the resuscitation area using direct observation. We had two trained and independent observers review case records to ascertain whether interventions were performed outside of the resuscitations area. Disagreements were resolved by third party assessments.

**Analysis**

We calculated the sensitivity and specificity of each level of ΔHgb in predicting the need for any of the index interventions, and used these operator characteristics to construct a receiver-operator curve for ΔHgb. Our primary outcome was the area under this receiver-operator curve (ROC), and its corresponding confidence interval.[6] We also calculated the maximum

Youden Index associated with the ROC. In determining our sample size, we estimated that we would need 251 patients to estimate the optimal sensitivity of serial hemoglobin measurements to within 5% (± 2.5%). In the setting of acute hemorrhage, common practice is to withhold administration of IV fluids and move straight to resuscitation with blood. Hence, we calculated an additional area under the ROC where administration of 3 or more liters of IV fluids was not considered an intervention.

**Results**

Our institution had 393 trauma activations between June 2016 and October 2016. We excluded 142 patients because they either underwent an index intervention prior to their second hemoglobin measurement, or met one of the exclusion criteria. The remaining 251 patients, including 192 males and 59 females with a mean age of 40, form our cohort. We found that no interventions were performed in 195 patients, while a total of 93 interventions were administered to the remaining 56 patients. Figure 1 provides the flow diagram for patient enrollment, and Table 1 documents the distribution of interventions among our cohort. An operative procedure was the only intervention provided to four patients (1.6% of all enrolled patients, and 7.1% of the patients receiving some form of intervention). Of the 19 patients who received fluid support as their only intervention, ten exhibited falling hemoglobin levels, five exhibited stable levels and four exhibited rising levels.

The median ΔHgb was -0.1 gm/dl (Interquartile range: -0.5 gm/dl to 0.1 gm/dl) for patients requiring intervention, and 0.0 gm/dl (Interquartile range: -0.6 gm/dl to 0.3 gm/dl) for patients not requiring intervention. Figure 2 depicts the frequency of ΔHgb measurements as a function of ΔHgb for cases with and without intervention.

Figure 3 presents the receiver operator curve for ΔHgb, with an area under the ROC of 0.53 (95% Confidence interval: 0.44 – 0.62). The maximum Youden Index of 0.15 corresponded to a sensitivity of 71.4% and a specificity of 43.6%.

Our inter-rater assessment revealed that our raters agreed on 94.7% of their assessments, exhibiting a kappa value of 0.88.

Administration of 3 or more liters of IV fluids was the only intervention performed in 19 of the 56 patients who received an intervention. Shifting these 19 patients into the non-intervention group left 37 patients who receive at least one of the remaining interventions, while 214 patients received no intervention. We found the area under the ΔHgb ROC for this revised classification to be unchanged at 0.53.

**Limitations**

Because our study excluded patients who received interventions prior to a second hemoglobin measurement, it is possible that our study underestimates the benefit of ΔHgb assessments that might be apparent had second measurements in these patients been obtained and included in our analysis. For example, many patients with obvious instability were rushed to the operating room prior to serial hemoglobin assessment. However, while it is likely that ΔHgb measurements in these patients would have enhanced the apparent ability of ΔHgb to detect the need for intervention, this additional information is mostly of academic interest as serial hemoglobin measurements were clearly of little value in determining the management of these patients. Thus, from a practical perspective, our study enrolled a suitable population for studying the effect of ΔHgb on actual decision-making.

We specifically chose a short interval for our ΔHgb assessments to focus on a time frame that is relevant to typical trauma resuscitations. It is possible that ΔHgb assessments may have greater utility if measured on longer time intervals.

Our study also focused on the value of serial hemoglobin levels in assessing the need for intervention among blunt trauma patients. We specifically excluded patients with penetrating trauma because operative and interventional decisions frequently involve concerns such as visceral injury that may not be associated with extensive blood loss.

It is also worth noting that our study was conducted at a single tertiary center in an urban environment, and our findings may not generalize to other centers with differing spectra of patients and differing practice patterns.

**Discussion**

The goal of early serial hemoglobin measurement is to aid in the detection of occult blood loss in the resuscitation suite, specifically in the blunt trauma population of our study. However, our results indicate that ΔHgb is no better than a coin toss (AUC = 0.53) in identifying patients who require intervention for ongoing hemorrhage. Many of our patients exhibited rising ΔHgb despite the fact that they had ongoing hemorrhage that ultimately required an intervention. Conversely, other patients exhibited falling ΔHgb, despite the fact that they did not require any interventions.

Explanations for the poor performance of ΔHgb are readily apparent in view of the events and fluid shifts that typically occur during blunt trauma resuscitations. Patients with risk of serious injuries typically receive intravenous fluids in the pre-hospital setting and in the emergency department prior to the first hemoglobin measurement. The administered fluid acts to expand the intravascular volume resulting in decreased hemoglobin concentrations that would be apparent on the initial hemoglobin assessment. As the administered fluid redistributes to interstitial and intracellular spaces, intravascular volume will decrease leading to a rise in hemoglobin concentration that will be evident on subsequent hemoglobin assessments. This process likely explains the rising ΔHgb we found in many of our patients who did not require intervention, but also likely explains the increasing hemoglobin concentrations we found in patients who did require intervention, where vigorous fluid resuscitation over-expanded the intravascular volume despite modest ongoing blood loss.

In a similar fashion, patients who received vigorous fluid administration after the initial hemoglobin measurement will be found to have decreasing hemoglobin concentrations on subsequent measurements strictly as a consequence of the dilutional effect of the administered fluids, even in the absence of ongoing hemorrhage. This likely explains the falling hemoglobin levels we found in many of the patients who did not require intervention.

While studies testing the validity of ΔHgb in blunt trauma patients is limited in literature, there is evidence suggesting that ΔHgb provides little to no diagnostic value in the non-operative management of patients presenting with blunt splenic trauma.[7] Our study extends this finding to the blunt trauma patient population as a whole. Early ΔHgb assessments not only fail to aid in the detection of occult blood loss in blunt trauma patients, but likely act to confuse and misdirect physicians in the resuscitation suite.

It is important to note that our study focused on early serial hemoglobin measurements and their ability to inform interventions in the resuscitation suite, particularly within the first five minutes of arrival to the resuscitation suite. It is possible that the utility of serial measurements differ on other time scales, with most studies taking serial measurements two to six hours apart.[8] Thorson and colleagues, in a study based on chart review, found that serial measurements were a good indicator of blood loss in trauma patients who had an initial assessment within the first 30 minutes of arrival and a second assessment within four hours,[1] but the study by Madsen suggests that serial measurements taken six hours apart rarely provide diagnostic information in trauma patients who are deemed stable for placement in observation units after the initial trauma screening.[5] Given that our assessment of the utility of serial hemoglobin primarily focused on the first five minutes of arrival to the resuscitation suite, our results cannot be generalized to different interval scales for serial hemoglobin measurements.

In summary, the results of our study indicate that at a level I trauma center, where blunt trauma patients are first taken to the resuscitation suites prior to transport to the scanners, operating room, or observation units, serial hemoglobin provides little to no use in the detection of occult blood loss. Furthermore, serial hemoglobin potentially misdirects and confuses the physicians and the rest of the trauma team in the resuscitation suites, decreasing the efficiency of the code trauma.

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**Table 1. The distribution of interventions among the blunt trauma cohort*.**

| Intervention | Number of administrations | Proportion of all patients (N = 251) | Proportion of patients receiving any intervention (N = 56) | Proportion of all interventions (N = 93) |
|---|---|---|---|---|
| **Operation alone** | 4 | 1.6% | 7.1% | 4.3% |
| **Embolization** | 0 | 0% | 0% | 0% |
| **Blood alone** | 4 | 1.6% | 7.1% | 4.3% |
| **Fluids alone** | 19 | 7.6% | 33.9% | 20.4% |
| **Exsanguination** | 0 | 0% | 0% | 0% |
| **Blood and fluids** | 20 | 8.0% | 35.7% | 21.5% |
| **Fluids and operation** | 3 | 1.2% | 5.4% | 3.2% |
| **Blood, fluids and operation** | 6 | 2.4% | 10.7% | 6.5% |
| **Fluid, blood and embolization** | 1 | 0.4% | 1.8% | 1.1% |
| | | | | |
| **Any fluid** | 48 | 19.1% | 85.7% | 51.6% |
| **Any blood** | 31 | 12.4% | 55.4% | 33.3% |
| **Any embolization** | 1 | 0.4% | 1.8% | 1.1% |
| **Any operation** | 13 | 5.2% | 23.2% | 14.0% |

*1 - Operation or procedure to control hemorrhage, 2 - radiographic embolization, 3 - administration of blood and blood products, 4 - administration of three or more liters of IV fluids, 5 - exsanguination.

Figure 1 – Patient Flow Diagram

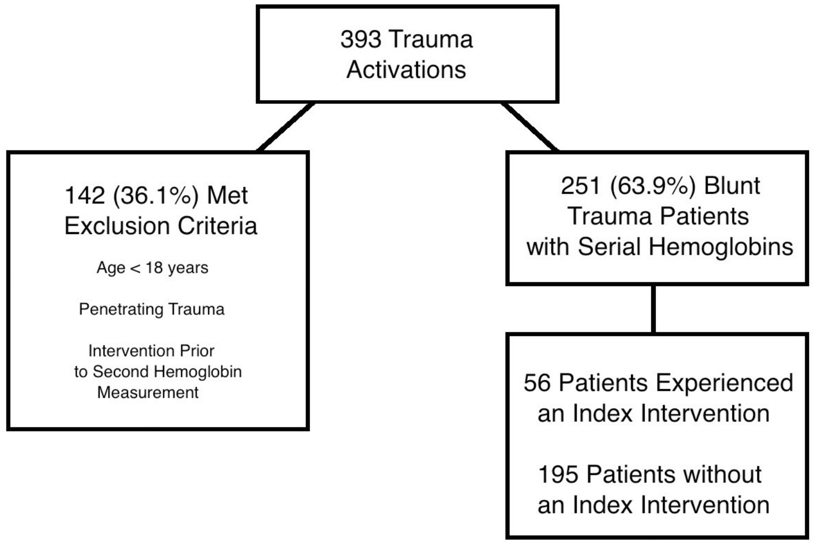

Figure 2 – Number of Interventions at Different “Changes in Hemoglobin” Levels

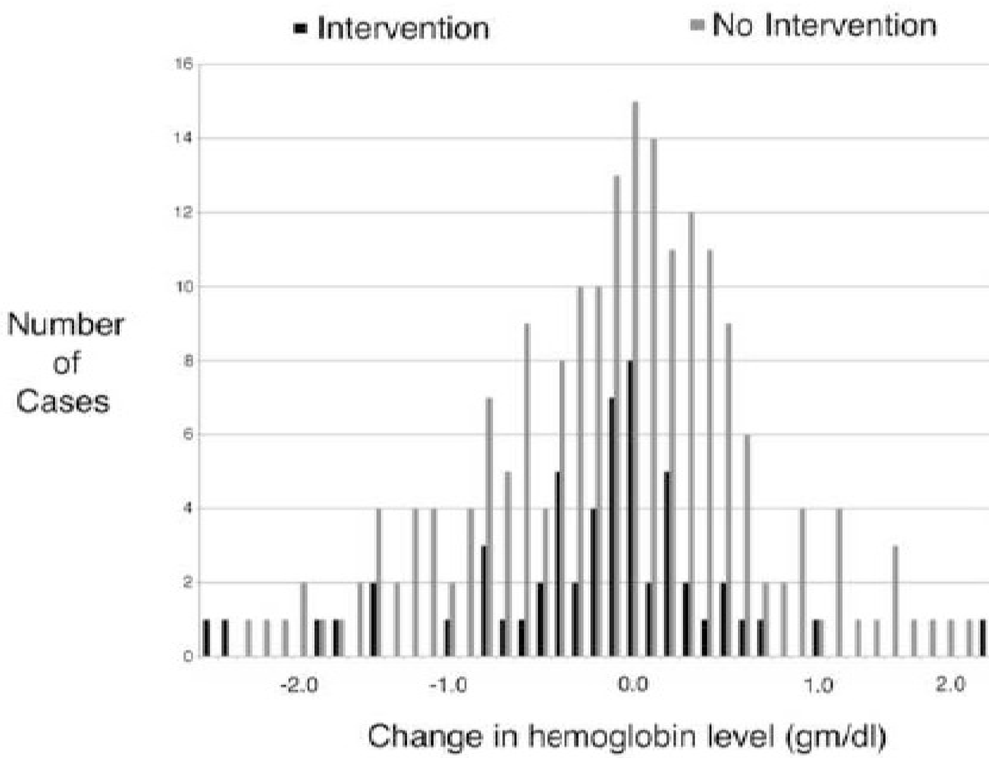

Figure 3 – Receiver Operator Curve for “Change in Hemoglobin”