

## Original Research Article

# Early detection with renal Doppler resistive index measurements of hemorrhagic shock in polytrauma patients

Nitishkumar Dhanajirao Yeslawath\*

Department of Radiology, Vinayaka Mission Medical College, Karaikal, Pondicherry-609609, India

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### \*Correspondence:

Dr. Nitishkumar Dhanajirao Yeslawath,  
E-mail: [drnithish@gmail.com](mailto:drnithish@gmail.com)

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## ABSTRACT

**Background:** Poly trauma is a major cause of morbidity and mortality in both developed and developing countries. The aim was to investigate whether renal Doppler RI changes occur early with posttraumatic bleeding and whether the renal Doppler RI may enable accurate prediction of occult hypoperfusion and thus be predictive of the development of hemorrhagic shock in polytrauma patients.

**Methods:** It was a prospective study involving patients admitted in the causality and evaluated by radiology department. Study was done in a period of 6 months from June 2016-December 2016. Renal Doppler RI was measured in 48 hemodynamically stable adult patients admitted in emergency because of polytrauma.

**Results:** 26 patients developed hemorrhagic shock, and 22 did not. Hemorrhagic shock group, as compared with the nonhemorrhagic shock group, had higher renal Doppler RI (mean,  $0.79 \pm 0.11$  [standard deviation] vs  $0.61 \pm 0.2$ ;  $P < 0.01$ ), injury severity score (mean,  $33 \pm 12$  vs  $25 \pm 9$ ;  $P < 0.01$ ), and standard base excess (mean,  $-4.0 \text{ mEq/L} \pm 4$  vs  $1 \text{ mEq/L} \pm 3$ ;  $P \leq 0.05$ ) values. At logistic regression analysis, a renal Doppler RI greater than 0.9 was the only independent risk factor for progression to hemorrhagic shock ( $P < 0.001$ ).

**Conclusions:** Renal Doppler RI measurement may represent a clinically useful non-invasive method for the early detection of occult hemorrhagic shock.

**Keywords:** Hemorrhagic shock, Polytrauma, Renal Doppler RI

## INTRODUCTION

Poly trauma is a major cause of morbidity and mortality in both developed and developing countries. The incidence and prevalence of poly trauma varies from region to region. The most common causes are road traffic accidents, fall from heights, bullet injuries, etc.<sup>1</sup> In civilian life, poly trauma is often associated with motor vehicle accidents. It may also result from blast injuries sustained by improvised explosive devices. Poly trauma patients represent the ultimate challenge to trauma care and the optimization of their care is a major focus of clinical research. The heaviest toll of traumatic deaths occurs within the first hour following trauma, often

defined as “the golden hour of trauma”.<sup>2</sup> Traumatic injury is the leading cause of death worldwide among persons aged 5-44 years and accounts for 10% of all deaths.<sup>3</sup> Despite improvements in trauma care, uncontrolled bleeding is the leading cause of potentially preventable early in-hospital deaths, contributing to 30%-40% of trauma-related deaths. About 30% more deaths occur within the second or third hour after injury owing to occult major internal hemorrhage.<sup>3</sup>

Hypovolemic shock, also known as hemorrhagic shock, is a life-threatening condition that results when you lose more than 20 percent (one-fifth) of your body’s blood or fluid supply. This severe fluid loss makes it impossible

for the heart to pump a sufficient amount of blood to your body. Hypovolemic shock can lead to organ failure. This condition requires immediate emergency medical attention. Internal bleeding symptoms may be hard to recognize until the symptoms of shock appear, but external bleeding will be visible. Symptoms of hemorrhagic shock may not appear immediately.

The Doppler resistive index (RI) was advanced as a useful parameter for quantifying the alterations in renal blood flow that may occur with renal disease. RI an intrarenal artery is the most frequently used for clinical investigations because this measurement does not require estimations of the Doppler angle or the vessel cross-sectional area.<sup>5</sup> Moreover, animal studies have shown that the renal Doppler RI is dependent on the perfusion pressure and is increased by hypotension in the presence of hypovolemia or normovolemic anemia.

The purpose of the present study was to investigate whether renal Doppler RI changes occur early with posttraumatic bleeding and whether the renal Doppler RI may enable accurate prediction of occult hypoperfusion and thus be predictive of the development of hemorrhagic shock in polytrauma patients

## METHODS

It was a prospective study involving patients admitted in the causality and evaluated by radiology department. Study was done in a period of 6 months from June 2016-December 2016. Renal Doppler RI was measured in 48 hemodynamically stable adult patients admitted in emergency because of polytrauma. This study was approved by the institutional ethics committee, and informed consent was obtained from all patients.

### Inclusion criteria

Low blood pressure (systolic blood pressure <90mmHg), low urine output (<30mL/h), and a blood lactate level greater than 2 mmol/L (features of hemorrhagic shock).<sup>23</sup>

### Exclusion criteria

Younger than 18 years or older than 65 years, hemoglobin level of 8g/dL or less, penetrating trauma, vasoactive drug support, abnormal creatinine level (>1.5mg/dL) or history of renal disease, diabetes, or free abdominal fluid diagnosed by means of focus assessment sonography for trauma (FAST).

Doppler resistive index was calculated according to Planiol and Pourcelot protocol.<sup>6</sup> For each of the three renal areas, three Doppler measurements were taken, and the mean values were then averaged to derive an index for the whole organ in order to minimize sampling error. Pulsed wave Doppler spectrum was increased by using the lowest frequency shift range that did not cause aliasing and the wall filter was set at a low frequency

(100 MHz). Values of renal Doppler resistive index >0.70 were considered abnormal, with normal values ranging between 0.48 and 0.68. Renal venous flow was evaluated to exclude the presence of occlusion or thrombosis.

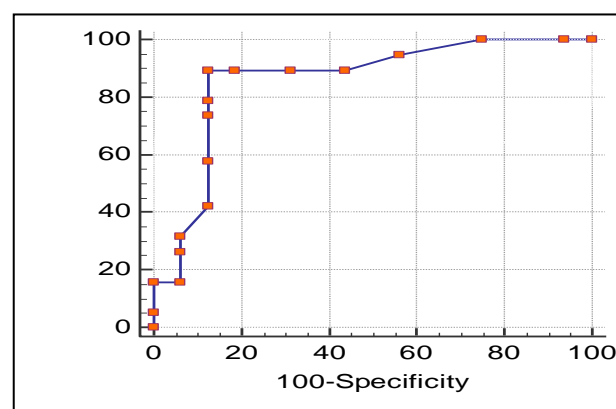
To minimize sampling error, the pulsed wave Doppler spectrum was increased by using the lowest frequency shift range that did not cause aliasing and the wall filter was set on a low frequency (100 MHz). Venous flow studies of the kidney were limited to evaluation of the patency of the vessels to exclude the presence of occlusion or thrombosis.

IVC was evaluated and measurements were taken at both inspiration and expiration during spontaneous tidal breathing. The difference (IVCi) was derived, and the IVC collapsibility index was calculated as (IVCe-IVCi)/IVCe to assess the intravascular volume in relation to the central venous pressure.

The following patient data were collected and recorded: sex, age, Injury severity score, time between occurrence of trauma and arrival at the hospital, time from hospital admittance to radiology department, systolic blood pressure, heart rate, blood lactate level, standard base excess, arterial pH, hemoglobin concentration, platelet count, intensive care unit admittance, length of hospital stay, and hospital mortality.

## RESULTS

In the period of 6 months total 189 patients were admitted in which 48 patients meet the inclusion criteria. 26 developed hemorrhagic shock within the first 24 hours after hospital admittance. 6 of these 25 patients died of multisystem organ failure. None of the 22 patients who did not develop hemorrhagic shock died or required emergency surgery were taken as controls (Table 1).

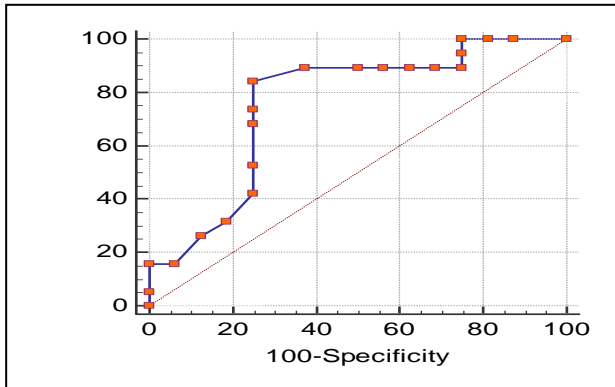


**Figure 1: Graphical presentation of Sensitivity and specificity for early detection of hemorrhagic shock, on ROC curves of renal Doppler RI.**

All the demographic characteristics are not significant except injury severity score, renal Doppler RI and

standard base excess Re significant in compared in both groups.

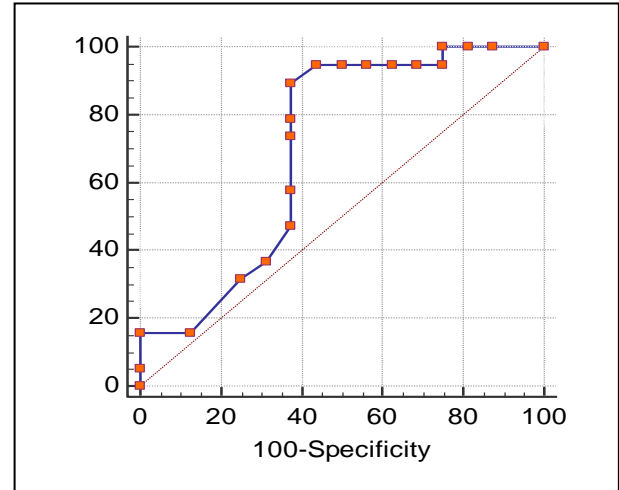
Renal Doppler RI is significantly predictive of early hemorrhagic shock and bleeding.



**Figure 2: Graphical presentation of Sensitivity and specificity for early detection of hemorrhagic shock, on ROC curves of Injury severity score.**

Areas under the receiver operating characteristic curves were significant for renal Doppler RI (area under curve,

0.91; ( $P \leq 0.05$ ), injury severity (area under curve, 0.71; ( $P = 0.07$ ), and standard base excess (area under curve, 0.701; ( $P \leq 0.05$ ). A renal Doppler RI greater than 0.7 was predictive of hemorrhagic shock, with 89% sensitivity and 87% specificity.



**Figure 3: Graphical presentation of Sensitivity and specificity for early detection of hemorrhagic shock, on ROC curves of standard base excess.**

**Table 1: Demographic details in study.**

| Characteristics                                 | Hemorrhagic shock<br>n=26 | No hemorrhagic shock<br>n=22 | P-value |
|---|---------------------------|------------------------------|---------|
| <b>Males</b>                                    | 18                        | 15                           | 0.89    |
| <b>Females</b>                                  | 8                         | 7                            |         |
| <b>Age</b>                                      |                           |                              |         |
| Males   | 35± 12                    | 36±11                        | 0.41    |
| Females   | 36±11                     | 37±13                        | 0.53    |
| Injury severity score                           | 33±12                     | 25±9                         | <0.01   |
| pH  | 7.36±0.04                 | 7.37±0.06                    |         |
| Time of accident to hospital(mins)              | 29±16                     | 30±18                        | 0.78    |
| Time of causality to Radiology department(mins) | 10±4                      | 10±3                         | 0.69    |
| Lactate llevel(mmol/L)                          | 3±1                       | 2±1                          | 0.05    |
| Hemoglobin level(g/dL)                          | 13±1.6                    | 13±1.8                       | 0.91    |
| Platelet count( $10^9/L$ )                      | 248±91                    | 258±87                       | 0.67    |
| Heart rate (bpm)                                | 94±21                     | 99±19                        | 0.29    |
| Systolic blood pressure(mm Hg)                  | 111±14                    | 112±15                       | 0.75    |
| Renal Doppler RI                                | 0.79±0.11                 | 0.61±0.2                     | <0.01   |
| standard base excess                            | -4±4                      | 1±3                          | <0.01   |
| IVC(mm)   | 14±4                      | 15±4                         | 0.39    |

**Table-2: Variables of Receiver operating curves.**

| Variable                     | Cut off value | Sensitivity | Specificity | AUC   | P-value |
|------------------------------|---------------|-------------|-------------|-------|---------|
| Renal Doppler RI             | 0.74          | 89          | 87          | 0.91  | <0.05   |
| Injury severity score        | 26            | 84          | 75          | 0.71  | 0.07    |
| Standard base excess (mEq/L) | -2.7          | 89          | 62          | 0.701 | <0.05   |

## DISCUSSION

Generally, among all patients admitted to the ED because of polytrauma, a relatively small number of patients in stable hemodynamic condition at ED admission eventually require massive transfusion (26 of 189 patients in our group). Yet, about 40% of them die within the first 6 hours after admission, and the total mortality rate may reach 60% despite the large amounts of total blood transfused. This is because even major occult bleeding may occur during the early phases after trauma without being recognized owing to the complex triage and screening procedures in overcrowded EDs. A delay in the diagnosis of occult bleeding can result in a greater than threefold increase in hospital mortality, and several studies have shown that early hemodynamic monitoring and aggressive resuscitation can reduce mortality among polytrauma patients.<sup>7</sup> Different scoring systems and markers of hypoperfusion, such as serum lactate and standard base excess measurements, have been proposed for identifying patients who will require massive transfusions.<sup>8,9</sup> Although predictive in the general trauma population, these methods are not suitable for predicting occult bleeding during the early phases in hemodynamically stable patients with blunt trauma. Use of the ISS and other anatomic scores requires knowledge of all anatomic injuries, and this determination may take hours after the ED admission. For this reason, these scores might not be useful for early screening.<sup>10</sup> Lactate levels have proved to be useful in predicting surgical intervention and hospital mortality rates but not bleeding or transfusion requirements. Moreover, in most of these studies, the patients were not stratified on the basis of hemodynamic stability; thus, conclusions cannot be generalized. However, initially elevated lactate levels and standard base excess values might be affected by numerous nonhypoxic causes of metabolic acidosis.

The concept of compensated shock and hemodynamic instability does not imply the presence of hypotension.<sup>11</sup> Even if the arterial blood pressure is normal, substantial maldistribution of blood flow to the vital organs may be present; this condition, termed cryptic shock, eventually may lead to organ dysfunction. Measurements of regional circulation have been shown in experimental models to be predictive of outcome. In critically ill patients, organ failure may result from inadequate tissue perfusion and oxygenation, contributing to increased mortality. Methods that are currently available for monitoring regional circulation are tonometry, laser Doppler flowmetry, indocyanine green clearance, lidocaine metabolism, and sublingual microcirculation tests; however, these techniques are time consuming and not immediately available in emergency settings.<sup>12</sup>

Patients with occult bleeding generally have relative hypovolemia or normovolemic anemia, which may result in vasoconstriction and increased vascular resistance. Because increased tissue resistance to perfusion slows the diastolic velocity more than it slows the systolic velocity,

these changes cause an increase in the RI that can be measured in parenchymal organs such as the kidneys.

The lack of a difference in the caval index or diameter between the two groups in present study was in contrast to previously published data.<sup>13</sup> This may be because only patients who were initially hemodynamically stable and without biochemical signs of hypoperfusion and had a very short delay between departure from the trauma scene to ED admission and US examination were included. Thus, we hypothesize that most of the patients were normovolemic at arrival in the ED despite having occult bleeding. We found that early changes in the renal cortical blood flow and renal Doppler RI were present independently of hemodynamic instability in normotensive patients after major trauma. The major advantages of using the renal Doppler RI measurement are that it is inexpensive, repeatable, and non-invasive and it could be rapidly performed in the ED in combination with other vital sign and gas-analytic parameter assessments as a completion of the focus assessment sonography for trauma examination.

This study provided information on the physiology of renal blood flow during the LT. The most striking findings were the increased renal RI in the an hepatic stage and decreased renal RI early after the reperfusion in a rat liver transplantation model. These results were different from the reports from Platt and Pompili, which showed that the increased RI before LT can revert to normal a week after transplantation.<sup>14,15</sup> RI measured at the different points can partially explain this apparent discrepancy, the RI values were initially measured on the first day after the operation but not immediately after the reperfusion, and the renal vasoconstriction due to the administration of cyclosporine (CSA) after operation can increase renal RI. The administration of CSA was associated with alterations in adrenergic tone and activation of the renin-angiotensin system

In a previous study, we demonstrated that renal Doppler RI measurement may also represent a clinically useful method for early detection of occult hemorrhagic shock.<sup>16</sup> For practical purposes, we believe that splenic compared with renal Doppler RI examination presents some practical advantages: (i) Doppler examination of a peritoneal organ, such as the spleen, is easier than examination of a retroperitoneal organ, such as the kidneys; (ii) the measurements of the splenic Doppler RI are much faster because less samples are required, being the spleen a single organ with larger vessels allowing faster examination; and (iii) the measurement of splenic Doppler RI may be more useful in the follow-up because the splenic artery is devoid of complex self-regulation such as kidneys, and thus it may directly reflect splanchnic perfusion as a terminal branch of mesenteric artery. This hypothesis should be validated by further studies comparing usefulness of splenic versus renal Doppler RI in follow-up of trauma patients. Doppler RI

to be an independent significant predictor of occult hemorrhagic shock with high sensitivity and specificity.

## CONCLUSION

In conclusion, present study results support the hypothesis that renal Doppler RI measurement may represent a clinically useful noninvasive method for the early detection of occult hemorrhagic shock.

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*Ethical approval: The study was approved by the institutional ethics committee*

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