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# EFFECTIVENESS OF THE LOCALLY MADE TOOL TO CONFIRM ACUTE COMPARTMENT SYNDROME BY WHITESIDES INFUSION TECHNIQUE

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## ABSTRACT

Acute limb compartment syndrome is an Orthopaedics emergency which demands accurate diagnosis and prompt management to save the limb and sometimes life. To avoid a missed diagnosis or an unnecessary fasciotomy, direct measurement of compartment pressure is required. The device, assembled locally with simple and easily available cheap tools, to measure the intracompartmental pressure in legs by Whitesides infusion technique, was found safe and effective. Aim of this study was to assess the effectiveness of the device for intracompartmental pressure measurement to confirm the clinically diagnosed compartment syndrome. This prospective observational study was conducted in NITOR on 50 patients enrolled by inclusion and exclusion criteria. Suspected cases underwent clinical and radiological evaluation. Blood pressure and anterior leg compartment pressure were measured. Delta pressure calculated and value less than 30 mmHg confirmed the clinical diagnosis. Determinant clinical findings were pain on passive stretching (86%) and blisters (44%). 43 (86%) cases were diagnosed to have acute compartment syndrome on clinical ground whereas in 40 (80%) cases the Delta pressure of less than 30 mmHg confirmed the diagnosis. No statistical difference was found between the two processes in the diagnosis of acute compartment syndrome in leg ($p = 0.616$). The study showed that 70% of the cases were positively diagnosed by both clinically and the device. It was thus concluded that the locally made device was effective in measurement of compartment pressure by Whitesides infusion technique.

***KEYWORDS:*** *Acute Compartment Syndrome, Locally assembled tool, Whitesides Infusion Technique, Intracompartmental pressure, Delta pressure.*

## INTRODUCTION

Acute compartment syndrome in limb is a dreaded consequence of limb injury and pose physical challenge to the person and economic burden to the society. It is defined as an increase in intra compartmental pressure (ICP) to a level and for a duration that without decompression will cause tissue ischemia and necrosis within a closed osseofascial compartment.[1] Localized swelling impairs the circulation and the cascade of inflammatory reaction initiated, leads to ischemia, necrosis and gangrene. Microvascular occlusion theory is the mostly accepted mechanism for reduction in capillary blood flow and subsequent tissue ischemia.[2] As the intensity & duration of the interstitial pressure increases, myoneural activity & function is declined and necrosis of the soft tissues eventually develops. Broadly two factors are responsible for this condition, either a decrease in compartment volume or an increase in the contents of a compartment. At times both act in concert. Proper evaluation and timely management prevent the grave consequences that may threaten the limb and sometimes live.

Pathological basis of developing acute compartment syndrome, irrespective of causes, is when the intra-compartmental pressure (ICP) exceeds the capillary pressure results in increased pressure at venous end and increased hydrostatic pressure. Arteriolar compression, compromised microcirculation and resultant tissue hypoperfusion ensues. Soft tissue ischemia, anoxia and eventual cell death follows inadequate perfusion and oxygenation.[3] The most ischemic vulnerable tissue in the compartment is the skeletal muscles. Magnitude of myonecrosis and cellular death dependent on duration of

ischemia, localize circulation, energy expenditure and temperature of the tissues.[4] The effect of missed diagnosis are serious and include rhabdomyolysis, acute renal failure, long-term motor-sensory deficit, amputation and even death.[5]

The classical clinical features of acute compartment syndrome traditionally include the six 'P's: pain, pallor, poikilothermia, paresthesia, paralysis and pulselessness. Pain & paresthesia usually the initial complaint and patients need a proper evaluation and workup for accurate diagnosis. Because of its subjective nature, although unlikely, the absence of pain cannot negate the possibility of the compartment syndrome[6] and again, paralysis, pulselessness and paresthesia appear late in the disease process, often after irreversible nerve and muscle damage and should not routinely be part of the diagnostic criteria.[7] Moreover, the diagnostic role and relative value of the clinical findings are debated. The symptoms and signs, which are usually subjective and cannot be determined unless patient is cooperative and alert, may sometimes lead to a diagnosis[8] but are often so ambiguous that a definite diagnosis cannot be made on clinical grounds.[9] Widely followed clinical feature to ascertain the compartment syndrome is unrelenting pain or pain in passive stretching which was showed to have sensitivity of 19% and specificity of 97%.[10]

In 1975, Whitesides et al[9] not only introduced the needle manometer technique to measure compartmental pressure also suggested that the compartment's perfusion depends on the differential or Delta (Δp) pressure (difference between diastolic BP and compartment pressure) and recommended fasciotomy when the compartment pressure rises to within the 30 mmHg of the diastolic BP. Afterwards, several other devices were developed, such as the Wick catheter, the slit catheter, the Stryker device and different transducer tipped catheters.[11] The later devices are expensive, not readily available in Bangladesh and neither easy to use nor to maintain. On the contrary, the device that is required for Whitesides infusion technique can be assembled locally with simple and easily available cheap tools. The process of measurement is also found safe and reproducible.[12] Studies in human limbs have revealed that the infusion technique yielded values that are virtually identical to those obtained from Wick catheter.[1] Therefore, this study was conducted to measure the rise of intracompartmental pressure in traumatized leg and to find out the effectiveness in confirmation of acute compartment syndrome.

## METHODOLOGY

This prospective observational study was conducted to measure the intracompartmental pressure by the locally made device for confirmation of clinical acute compartment syndrome in National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR) from February, 2017 to December, 2018. Once patients were suspected to have compartment syndrome in the injured leg, we enrolled them in the study when within 18-60 years of age, presented within 6 hours of initial accident and admitted in the hospital with complaints of injury to the leg with or without fracture of bone (if the fracture is open then Gustillo type I open fracture). Ethical clearance was taken from the Institutional Review Board. All potential subjects were informed verbally about the underlying objectives of the study, advantages, risks associated with their participation and their rights to withdraw themselves from the study at any time for any reasons whatsoever. It was also conveyed that the information generated from the study would be utilized for the patients alone and would not be disclosed anyway.

All selected patients underwent clinical and radiological evaluation and a provisional diagnosis was made. Afterwards, we measured the anterior compartment pressure in the injured leg with the locally assembled tool by Whitesides infusion technique. Patient's blood pressure was recorded. The delta pressure thus obtained was used to confirm the clinical suspicion of compartment syndrome. Once the clinical suspicion was confirmed by the delta pressure, urgent decompression fasciotomy of leg was advised.

***Compartmental pressure measurement*:** The compartment pressure was directly measured in the anterior compartment of leg 5 cm away from the fracture (if any). To assemble the device we used two IV extension tubes, two 18G needles, one 20 cc syringe, sterile normal saline, one mercury manometer (cuff removed) and one 3-way stopcock channel.

***Steps in measurement technique:*** The skin over the compartment was cleaned and prepped. A 20 cc syringe with the plunger at 15 cc mark, a 3-way stopcock, a plastic IV extension tube and an 18 G needle was assembled, normal saline without bubbles approximately half of the length of the extension tube was drawn and the 3-way stopcock was turned to close off this tube so that the saline is not lost during the transfer of the needle. Another extension tube was thus connected to the manometer on one end while 3way channel on the other end. We changed the needle and inserted into the muscle of the leg compartment.

***Assessment of Delta Pressure*:** The difference between the diastolic blood pressure and intracompartmental pressure is called the Delta pressure or differential pressure or muscle perfusion pressure (MPP). The perfusion of the compartment depends on it. Fasciotomy is recommended when the compartment pressure rises to within 30 mm Hg of the diastolic blood pressure.[9]

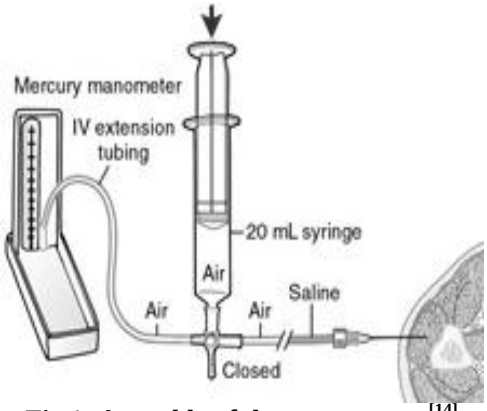


**Fig 1: Assembly of the components.**[14]

***Statistical analysis*:** The diagnosis of acute compartment syndrome in leg was made both on clinical ground and on the calculated delta pressure. The frequencies of diagnosed cases made by either of the methods were cross-tabulated and correlation established. Then chi-square test was done between the frequencies of diagnosis made by the two processes. Due to lack of suspected cases of acute compartment syndrome in the forearms, we assessed the injured legs only. We wish to apply the same technique in assessment of the injured upper limbs whenever necessary. The raw data was compiled and tabulated according to key variables. Master data sheet formulated. Editing of the collected data and all statistical analysis of different variables was done by SPSS (Statistical Package for Social Science), using appropriate formula. Table and graphs presented the results.

## RESULT AND OBSERVATION

**Table 1: Demographic features study population (n=50)**

| Variables | Frequency | Percentage |
|---|---|---|
| Age (yr.) | | |
| <20 | 4 | 8.0 |
| 20-40 | 32 | 64.0 |
| 41-60 | 14 | 28.0 |
| Sex | | |
| Male | 45 | 90.0 |
| Female | 5 | 10.0 |

Demographic features mentioned in Table 1. Age distribution revealed, 32 of the patients were in the group of 20-40 years (64%), 11 were in 41-50 years (11%), 4 was less than 20yrs and three were above 50 years of age. Most of the patients in this study were male (45). The male and female ratio was 9:1.

According to the visual analogue scale of pain, during presentation, 24 showed 5-7 score and 26 showed more than seven. There was pain on passive stretching on 43 cases (86%).

**Table 2: Distribution of cases according to Clinical manifestation (n=50)**

| Clinical manifestation | Frequency | Percentage |
|---|---|---|
| Pain | 50 | 100.0 |
| Pain on passive stretching | 43 | 86.0 |
| Paresthesia | 1 | 2.0 |
| Distal pulsation | | |
| Well felt | 47 | 94.0 |
| Feeble | 2 | 4.0 |
| Absent | 1 | 2.0 |
| Clinical impression of acute compartment syndrome | | |
| Yes | 43 | 86.0 |
| No | 7 | 14.0 |

**Table 3: Evaluation of Diastolic blood pressure (DBP), anterior compartment pressure (ACP) & Delta pressure (n=50)**

| Variables | Frequency | Percent |
|---|---|---|
| Diastolic BP (mm Hg) | | |
| 60 | 11 | 22.0 |
| 65 | 1 | 2.0 |
| 70 | 26 | 52.0 |
| 75 | 1 | 2.0 |
| 80 | 11 | 22.0 |
| Mean ± SD | 70.0 ± 6.7 | |
| Anterior Compartment Pressure (mm Hg) | | |
| 25 | 4 | 8.0 |
| 30 | 1 | 2.0 |
| 35 | 6 | 12.0 |
| 40 | 5 | 10.0 |
| 45 | 16 | 32.0 |
| 50 | 11 | 22.0 |
| 55 | 7 | 14.0 |
| Mean ± SD | 43.9 ± 8.4 | |
| Delta pressure | | |
| Mean ± SD | 26.6 ± 8.4 | |

Mean DBP being 70.0 mmHg with standard deviation of 6.776. Anterior compartment pressure as recorded by the locally made tool using Whiteside infusion technique after counselling and consent. Mean pressure being 43.9 mmHg. Difference between Diastolic blood pressure and anterior compartment pressure is the differential / delta / muscle-perfusion pressure. Mean delta pressure was 26.6 mmHg (Table 3).

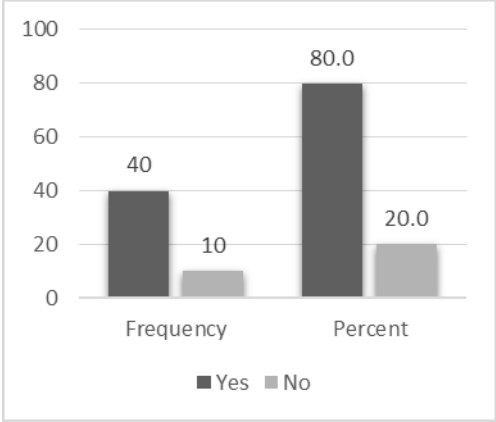


**Fig 2: Diagnosis of compartment syndrome based on delta pressure value obtained by locally made tool (n=50)**

**Table 4: Correlation of clinical diagnosis with diagnosis by locally made tool (n=50)**

| Clinical diagnosis | Diagnosis by the tool | | | |
|---|---|---|---|---|
| | Yes | % of n | No | % of n |
| Yes | 35 | 70 | 8 | 16 |
| No | 5 | 10 | 2 | 4 |

Table 4 shows the correlation of clinical diagnosis with diagnosis by locally made tool. True positive cases were 70.0%. So compartmental pressure by the locally made device for confirmation of acute compartment syndrome correlates with clinical diagnosis.

## DISCUSSION

In this study, 72% of the cases belong to the age group of 18 to 40 years. Mean age of the population was 35.21 years. This group of people are supposed to be more active, involved in outdoor activities and therefore injuries to their limbs affect profoundly to their functional, social and economic performances.

The site of involvement in leg was proximal tibia and diaphysis in 78% cases. Epidemiologically, youth has been found to be the most important risk factor for developing acute compartment syndrome, possibly

because of the relatively high muscle bulk in a fixed compartment.[10]

Of many proposed diagnostic tools, intra-compartmental pressure measurement remains the only widely accepted method. In our study, we used a locally made tool to measure intra compartmental pressure by Whitesides infusion method. This tool was constructed according to the guidance of the original literature by Whitesides Jr. et al.[9] Studies in human limbs have revealed that the infusion technique yields values that are virtually identical to those obtained from Wick catheter.[1] The device was also found to be inexpensive, safe and ideal for use in hospitals with limited resources in a developing country.[12] We also found the locally made tool was easy to use, cheap and safe and did not encounter any complication during pressure measurement in the anterior compartments of the cases. The construction of the device costed only 2000 BDT (25 USD/ 20 Euro).

In this study mean delta pressure was 26.6 mmHg and diagnostic accuracy was 70.0% cases. McQueen et al, in a prospective study for tibial diaphyseal fractures, concluded that a threshold delta pressure of 30 mmHg for decompression in acute compartment syndromes had led to "no missed cases, unnecessary fasciotomies or significant complications".[13] We, as well, used the delta pressure less than 30 mmHg to establish the diagnosis of acute compartment syndrome. We also found that those who showed pain on passive stretching also had higher anterior compartment pressure (44.5 mmHg ± 8.1). However, this finding was not statistically significant, possibly due to smaller sample size or due to subjective variation in expression of pain.

In our study, the cases were selected when we had suspected the possibility of development of compartment syndrome based on swelling of the legs that were firm on palpation. All the cases were first assessed clinically and thereafter pressure measurement done by the locally made tool. Among those, 43 (86%) were diagnosed on clinical ground and 40 (80%) were confirmed by the locally made tool. There were eight cases who had positive clinical diagnosis but delta pressure were more than 30 mmHg. Five cases who had negative clinical diagnosis showed delta pressure <30 mmHg. Two cases were not diagnosed positively either clinically or by differential pressure. The p-value calculated by chi-square test was 0.616, which is statistically non-significant. This result indicated that values measured by the locally made tool with Whitesides infusion technique were as effective as clinical ground in diagnosis of acute compartment syndrome. Therefore, this method will be able to diagnose the condition even in situations where clinical features are difficult to elicit.

## CONCLUSIONS

Due to the increased events of motor vehicle accidents and other high velocity injuries, incidences of acute compartment syndrome are also increasing in numbers. In most of the cases compartment syndrome can be diagnosed clinically and prompt decompression could be done to save the limb. Present study concluded that the locally made tool was able to measure intracompartmental pressure accurately by Whitesides infusion technique. Thereby, it was able to confirm the clinical suspicion of acute or impending compartment syndromes in limbs. This method should be widely implemented in the developing nations as a routine procedure in order to diagnose limb compartment syndrome promptly and to manage effectively.

**Ethical Issue:** A well-informed, voluntary, signed written consent was taken in Bangla from the study subjects before enrollment after convincing them that privacy, anonymity, and confidentiality of data information identifying any patient would be maintained strictly. Each patient enjoyed every right to participate or refuse or even withdraw from the study at any point in time. The protocol was approved by the Ethical Review Board of NITOR.

**Conflict of Interest:** Authors declare no conflict of interest.

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