

## Post-Surgical Hyponatraemia: Problems of Management Resolved by Revealing its Relation to Volumetric Overload Shocks

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### Abstract

Hyponatraemia (HN) is well known in urology as the transurethral resection of the prostate (TURP) syndrome. It also affects postsurgical patients of men, women and children. It has high morbidity and mortality. Its clinical picture reflects multiple vital organ dysfunction/failure syndrome. The central nervous system is affected with coma, cardiovascular system is affected with shock and bradycardia and respiratory system is affected with pulmonary oedema and the acute respiratory distress syndrome (ARDS). Anuria or acute renal failure occurs. The objective of this article is to show that postsurgical hyponatraemia initially presents with vascular shock that initiate the wrong therapy of vascular volume expansion with lethal outcome. The correct therapy for the condition is hypertonic sodium therapy.

Recent research demonstrated that HN initially presents with volumetric overload shock that is usually mistaken for recognised shock and treated with further volume expansion resulting in death. Volumetric Overload Shock (VOS) is a condition caused by massive fluid infusions in a short time and is of two types; Type one (VOS1) and Type two (VOS2). VOS1 is induced by sodium-free fluid gain of 3.5 - 5 litres in one hour. It is known as the TURP syndrome or HN shock. VOS2 is induced by massive infusion of sodium-based fluids that may complicate the therapy of VOS1. VOS2 also complicates fluid therapy in critically ill patients suffering from other known shocks and presents with ARDS. Clinical research demonstrated that hypertonic sodium therapy is life saving. Physics research on the hydrodynamics of the porous orifice tube proved that Starling's law for the capillary-interstitial fluid transfer is wrong and provided a replacement. The presented evidence should resolve the puzzle of HN, TURP syndrome and ARDS.

**Keywords:** Hyponatraemia; Shock; The Transurethral Prostatectomy Syndrome (TURS); The Adult Respiratory Distress Syndrome (ARDS); Starling's Law; Capillary Hydrodynamics

### Abbreviations

VOS: Volumetric Overload Shocks; VOS1: Volumetric Overload Shock Type 1; VOS2: Volumetric Overload Shock Type2; TURP: The Transurethral Resection of The Prostate; ARDS: The Adult Respiratory Distress Syndrome; MVOD: The Multiple Vital Organ Dysfunction/Failure Syndrome;

HN: Hyponatraemia; HST: Hypertonic Sodium Therapy; G Tube: The Porous Orifice Tube

### Introduction

Hyponatraemia (HN) in which serum sodium is < 130 mmol/l is one of the most commonly encountered biochemical abnormality in clinical practice [1,2]. Batuman., *et al.* [3] found that HN affects 33% of patients receiving parenteral nutrition (range 114 - 129 mmol/l). In a prospective study involving surgical patients, Chung., *et al.* [4] found post-operative HN to affect 23.1% cardiovascular, 18.9% Gastro-intestinal and biliary and 92% renal transplantation patients. Anderson., *et al.* [5] found that 1 - 2.5% of hospitalized patients had HN and was associated with a 60-fold increase in fatality.

The fatality of HN is well documented [1,2,6-8]. Professor Arieff reported on fatality of HN in children [6], in women undergoing elective surgery [7] and in women after endometrial ablation [8]. The most famous example of HN is the transurethral resection of the prostate (TURP) syndrome [9], which has 10% morbidity and 1% mortality [10]. The morbidity and mortality of acute HN is dependent on

the level to which serum sodium drops and the rate of this fall. An acute reduction in serum sodium concentration of > 20 mmol/l or to a level below 120 mmol/l is usually serious, but may be asymptomatic if time is allowed for adaptation [5] or osmolality is maintained. At levels less than 130 mmol/l, HN causes delirium and confusion. At level of < 100 mmol/l, HN is fatal. The objective of this article is to show that postsurgical hyponatraemia initially presents with vascular shock that initiate the wrong therapy of vascular volume expansion with lethal outcome. The correct therapy for the condition is hypertonic sodium therapy.

### Clinical picture of HN

The clinical picture of HN of the TURP syndrome reflects multi-system vital organ dysfunction/failure (MVOD/F) syndrome. Vital organs are affected singly or in combinations [14,15]. The central nervous system [16], cardiovascular system [17] and respiratory system [18] are affected. Anuria or acute renal failure which is resistant to diuretics occurs [19]. Coagulation disorders [20] and hepatic dysfunction may also occur.

### The cerebral features of HN

Manifestations of the cerebral nervous system are recognized early in the conscious patient who received regional anaesthesia. Mild signs such as confusion, delirium, disorientation, restlessness, apprehension, burning all over the body, irritability, lethargy, headache, muscle twitching, nausea and vomiting are commonly observed early features. Visual disturbance of transient or permanent bilateral blindness have also been reported [11,12].

The patient may progress to severe signs such as convulsion, coma with fixed dilated pupils and bizarre types of paralysis which mimic cerebro-vascular infarctions [13]. Coma and paralysis may be the presenting signs in patients who had general anaesthesia from which he fails to recover. Intensive investigations may be embarked upon causing delay in treatment. Not uncommonly the diagnosis may be missed leading to permanent brain damage with coma or death [6-8].

### The cardiovascular features of HN

Cardiovascular manifestations include a transient phase of hypertension and bradycardia which is followed by hypotension and bradycardia [22]. Hypotension may be also associated tachycardia – a confusing situation that mimics hypovolaemic shock and may lead to misguided attempt to give more isotonic fluids and blood transfusions [23].

Other types of cardiac dysrhythmia may occur up to cardiac arrest and death [24]. Electrocardiographic (ECG) changes may suggest ischaemia of infarction. They include wide QRS complex of increased amplitude, depressed S-T segment, T wave inversion and dysrhythmias on ECG [15,25]. Elevated cardiac enzymes have been reported, in the absence of vascular ischaemia, during a routine TURP procedure and it has been reported in the TURP syndrome [9,24]. Interestingly the same findings were found in animals overloaded with irrigating fluids [17]. An early increase and later decrease in CVP, pulmonary capillary wedge pressure and cardiac output occurs.

Transient hypertension and bradycardia appear first in the anaesthetised patient [26]. When these changes are overlooked during the procedure, postsurgical hyponatraemia initially presents with vascular shock that initiate the wrong therapy of vascular volume expansion with lethal outcome. Delayed recovery from the anaesthetic may progress directly to convulsion, coma, respiratory or cardiac arrest [13].

### The respiratory features of HN

Respiratory manifestations of the TURP syndrome are those of pulmonary oedema [25] and the adult respiratory distress syndrome (ARDS) [26,27]. The increase in lung water has been confirmed by the decrease in electrical thoracic and cardiac impedance. Basal pulmonary crepitation, coarse bubbling, frothing around the mouth, cyanosis and decreased arterial oxygen, in spite of good oxygenation, may progress to respiratory arrest, prolonged respiratory insufficiency [17] or ARDS.

### Other systemic features of HN

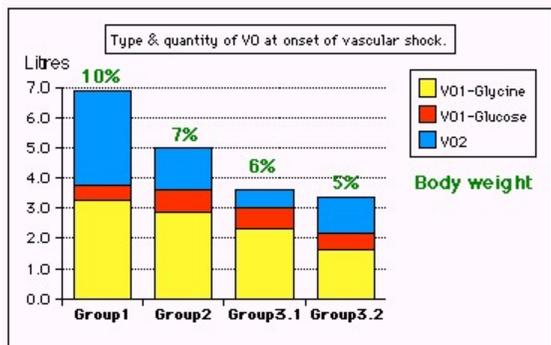
Massive peritoneal and pleural effusions have been reported in the TURP syndrome [29,30]. Abdominal pain in the absence of bladder perforations may occur, as may small and large bowel ileus. Venous bleeding from the prostatic veins may occur towards the end of the procedure and may be difficult to control [14,15]. In this type of bleeding no coagulation abnormalities are detected [31]. This is due to the early venous engorgement as a result of hypervolaemia [22]. Other bleeding syndromes due to coagulation abnormalities or disseminated intravascular coagulation may occur as late events [31].

**Patho-aetiology of HN and Volumetric Overload Shocks (VOS)**

The initial presentation of HN during surgery or immediately at postoperative period is severe hypotension reaction or shock with bradycardia. Although it was reported as hyponatraemic shock [2] it was realised recently to be induced by volumetric overload of sodium-free fluid. It is usually mistaken for one of the recognized shocks such as haemorrhagic [32] or septicaemic shocks [33]. The immediate response of treating physician is to give large volume of isotonic fluids for vascular expansion to correct hypotension using volumetric overload of sodium-based fluids such as saline, Hartman, plasma and or plasma substitutes. This has drastic results and death or falsely corrects HN and transfer the TURP syndrome into ARDS [34].

Volumetric Overload Shock (VOS) is a condition caused by massive fluid infusions in a short time and is of two types; Type one (VOS1) and Type two (VOS2). VOS1 is induced by sodium-free fluid gain of 3.5-5 litres in one hour such as Glycine, Glucose, Mannitol and Sorbitol. It is known as the TURP syndrome or hyponatraemic shock [9,27]. VOS2 is induced by massive infusion of sodium-based fluids such as normal saline, Ringer, Hartmann, plasma, plasma substitutes and blood transfusions that may complicate the therapy of VOS1. VOS2 also complicates fluid therapy in critically ill patients suffering from other known shocks such as hypovolaemic, haemorrhagic and septicaemic shocks and presents with ARDS [35,36]. VOS2 is induced by the gain of 12 -14 litres of sodium-based fluids when reported in ARDS. The occurrence of massive interstitial tissue oedema with congestion of vital organs, pleural and peritoneal effusions, in the presence of hypotension shock, casted doubt on Starling’s law! These issues were investigated at the clinical and physiological/physical fronts [36-38].

Two clinical studies aiming to understand the TURP syndrome and recognising VOS were done. A prospective clinical study on 100 consecutive TURP patients of whom the condition of TURP syndrome affected 10 patients with severe hypotension and bradycardia and severe acute dilution HN of < 120 mmol/l [9,30]. Volumetric overload was the only significant factor in causing the condition. The second clinical study involved a case series of 23 cases of the TURP syndrome manifesting as VOS1 [38]. Volumetric overload quantity and type is shown in figure 1. The first 3 cases died as they were diagnosed and treated erroneously as one of the recognised shocks and treated with further volume expansion. The remaining 20 patients were correctly diagnosed as VOS1 and treated with hypertonic sodium therapy (HST) of 5% Sodium Chloride or 8.4% Sodium Bicarbonate. Each patient passed 4-5 litres of urine followed by recovery from shock and coma. This treatment was successful in curing all patients bringing them back from dead [38].



**Figure 1:** Shows volumetric overload (VO) quantity (in litres and as percent of body weight) and types of fluids. Group 1 was the 3 patients who died in the case series as they were misdiagnosed as one of the previously known shocks and treated with further volume expansion. Group 2 were 10 patients from the series [38] who were correctly diagnosed as volumetric overload shock and treated with hypertonic sodium therapy (HST). Group 3 were 10 patients who were seen in the prospective study [30] and subdivided into 2 groups; Group 3.1 of 5 patients treated with HST and Group 3.2 of 5 patients who were treated with guarded volume expansion using isotonic saline. Comparing the results affirmed superiority of HST.

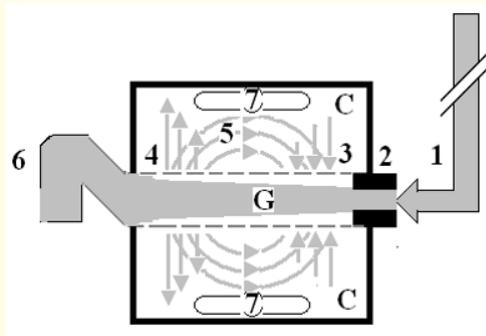
The physics investigation involved studies of the hydrodynamics of the porous orifice (G) tube [37] comparing it to that of Poiseuille’s tube. Thousands of experimental measurements of pressures at various parts of a circulatory system incorporating the G tube in a chamber to mimic the capillary-interstitial fluid compartment [37,38]. The effect of changing the proximal (arterial), the distal (venous) pres-

tures and the diameter of the inlet on side pressure of the G tube and chamber pressure as well as the dynamic magnetic field like fluid circulation around the G tube were investigated. It is quite remarkable how this circulatory model mimic the circulatory system in health and disease. This dynamic magnetic field like fluid circulation around the G tube and surrounding it in C chamber provides adequate replacement for Starling’s law. The physiological equivalent of this physics study was done on the hind limbs of sheep. It demonstrated that arterial pressure causes suction not filtration due to the effect of pre-capillary sphincter. It is the only possible explanation why the interstitial tissue pressure is negative [39]. Venous pressure augmented filtration and oedema or dropsy formation.

Shock is a disturbance at the capillary cellular level impairing the capillary-interstitial fluid transfer; hindering delivery of oxygen and removal of waste products. The process is governed by Starling’s law (1886). In this law the arterial pressure is considered the force causing capillary filtration! If this is true, how come that arterial hypertension though very common never causes oedema? Starling based his hypothesis on Poiseuille work on strait uniform brass tubes. Latter evidence however demonstrated that the capillary is a porous narrow orifice (G) tube as it has a pre-capillary sphincter [40] and pores that allow the passage of plasma proteins [41]. As the capillary pores allow the passage of plasma molecules, nullifying the osmotic pressure of plasma proteins i.e. oncotic pressure does not exist, a call for reconsideration of Starling’s hypothesis was previously made but there was no alternative at that time. This replacement came to light when the hydrodynamics of the G tube were discovered.

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The hydrodynamics of the G tube [37] (Figure 2) demonstrated that the proximal (arterial) pressure induces a negative side pressure gradient on the wall of the G tube causing suction most prominent over the proximal half and turns into positive pressure over the distal half. Incorporating the G tube in a chamber (C), representing the interstitial space surrounding a capillary, demonstrated a rapid dynamic



**Figure 2:** Shows Diagram of the porous orifice (G) tube enclosed in chamber (C) based on several photographs demonstrating the magnetic field-like G-C circulation phenomenon [37]. The proximal inflow (arterial) pressure (1) pushes fluid through the orifice (2) creating fluid jet in the lumen of the G tube. The fluid jet creates negative side pressure gradient causing suction maximal over the proximal half of the G tube near the inlet (3) that sucks fluid into lumen. The side pressure gradient turns positive pushing fluid out of lumen over the distal half maximally near the outlet (4). Thus the fluid around G tube inside C moves in magnetic field-like fluid circulation (5) taking an opposite direction to lumen flow of G. tube. The inflow (arterial) pressure (1) and orifice (2) induce the negative side pressure energy creating the dynamic G-C circulation phenomenon that is rapid, autonomous and efficient in moving fluid out from the G tube lumen at (4), irrigating C at (5), then sucking it back again at (3), maintaining net negative energy pressure (7) inside C. The distal outflow (venous) pressure (6) enhances outflow at (4) and its elevation may turn the negative energy pressure (7) inside C into positive, increasing volume and pressure inside C chamber.

magnetic field-like fluid circulation between the C and G tube lumen. This is a mixing engine between C and G effecting rapid irrigation under negative pressure i.e. without flooding or oedema or dropsy formation. Incorporating the G tube and C in a circulatory model driven by electric pump inducing proximal pressure similar to arterial pressure; causing suction from C into the lumen of G tube. The distal (venous) pressure augments filtration. This proves that the arterial pressure causes suction not filtration at the capillary interstitial fluid circulation, and hence Starling's law is wrong [36,37]. The reported hydrodynamics of the G tube provides an adequate mechanism for the capillary interstitial fluid circulation. The above presented evidence should resolve the puzzle of HN, TURP syndrome and ARDS.

### Conclusion

This article reviews the literature on postsurgical HN showing its high morbidity and mortality. It demonstrates that the initial presentation is with vascular hypotension shock before HN is measured. This initiates the wrong therapy of giving further fluid with the aim of vascular expansion to correct shock. This transfers VOS 1 into VOS2 that is lethal or presents with ARDS. So linking postsurgical HN to Volumetric overload shocks holds the key for initiating the correct therapy of hypertonic sodium therapy that saves the patients lives. The presented evidence is based on 2 clinical studies and physics study on the dynamics of the porous orifice (G) tube that should replace Starling's law on the capillary-interstitial fluid transfer. This will no doubt resolve the puzzle of postsurgical hyponatraemia, the TURP syndrome and ARDS.

### Conflict of Interest

None declared.

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### Patients and Public Involvement

Neither patients nor public were involved in writing this manuscript.

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