International Journal of Medical Science and Clinical Research Studies

ISSN(print): 2767-8326, ISSN(online): 2767-8342

Volume 04 Issue 08 August 2024

Page No: 1585-1595

DOI: https://doi.org/10.47191/ijmscrs/v4-i08-30, Impact Factor: 7.949

Fluid Overload Syndrome in Patients Undergoing Holmium Laser Enucleation of the Prostate (HoLEP)

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ABSTRACT

Introduction: Fluid overload syndrome is a potentially serious complication that can arise during holmium laser prostate enucleation (HoLEP) surgery. This minimally invasive surgical technique is used to treat benign prostatic hyperplasia (BPH) and is known for efficacy and safety. Fluid overload occurs when the patient receives excessive volume of intravenous fluids during the surgical procedure. This can occur due to a variety of factors, such as inadequate fluid administration by the medical team, excessive fluid absorption during irrigation, or systemic absorption of solutions used during surgery.

Material And Methods: A descriptive, observational, single-center and retrospective study was performed in patients undergoing prostatic enucleation with Holmium laser (HoLEP) who developed water overload syndrome, between April 2023-2024 in the Hospital Juarez of Mexico. The demographic data and the dependent variables will be tested for normality according to the Kolmogorov-Smirnov test with Lilliefors correction. If the data are normally distributed, factorial ANOVA will be used for more than two independent samples where the Bonferroni test will be used post Hoc for the multiple pairwise comparison in a parametric manner, considering $p<0.05$ as statistically significant; if the data are not normally distributed, the Kruskal- Wallis test will be used for more than two independent samples where the Dunn's test will be used post hoc forthe multiple pairwise comparison in a non-parametric way, considering $p<0.05$ as statistically significant.

Results: We analyzed 142 files of patients who underwent HoLEP, of which only 49 met the expected inclusion criteria. Of the remaining 49 files, 100% were men with a median age 69 years (58-79 years), weight 62 kg (58-78 kg), height 1.67 m (1.55-1.74 m), BMI 22.1 kg/m2 (21.7-25.8 kg/m2) and body surface area 1.69 m2 (1.61-1.71 m2). The hemodynamic and gasometrical variables were recorded at the anesthesia beginning, at 30, 60, 90, 120, 150 minutes and at the anesthesia end: At 60 minutes after Holmium enucleation the hemodynamic variables: systolic blood pressure 116 mm Hg (110-119 mm Hg), Diastolic blood pressure 63.5 mm Hg (56.5-67 mm Hg), Mean arterial blood pressure 81 mm Hg

ARTICLE DETAILS

Published On:
31 August 2024

(76.3-83.3 mm Hg), Heart Rate 68.6 beats/minute (62.6-73.6 beats/minute), Pulse Variability 4.45% (1.7-7.2%) and Plethysmographic variability 5.2% (2.2-8.2%). As for the gasometrical variables: pH 7.34±0.02, CO2 partial pressure 32.24±1.80 mm Hg, O2 partial pressure 61.61±1.80 mm Hg, Arterial Bicarbonate 17.84±1.26 mmol/L, Base deficit -3.95±0.53 mmol/L, Arterial Sodium 135.78±1.41 mmol/L, Arterial Potassium 3.02±0.15 mmol/L, Arterial Chlorine 103.97±1.95 mmol/L, Arterial Lactate 1.76±0.22 mmol/L and Coefficient p50 26.59±0.98 mm Hg. After statistical analysis with Kruskal-Wallis and Dunn-Bonferroni method, the hemodynamic and gasometrical changes occurring after 60 minutes are statistically significant ($p<0.05$).

Discusion: In this cohort of patients with fluid overload, they respond to myocardial fiber distension to a variable degree by increasing cardiac output and stroke volume until dysfunction occurs due to myocardial insufficiency. Myocardial depression in turn produces microvascular dysfunction with alterations in the regulatory functions of the endothelium. This behavior is demonstrated by changes in systolic, diastolic, and average blood pressure that compensate for fluid overload within the first 90 minutes of surgery. Few studies have reported the clinical outcomes of patients undergoing HoLEP, with hemodynamic behavior variables being the least described. If this fluid infusion is continued through prostatic reabsorption of sodium chloride, heart failure occurs due to activation of the sympathetic nervous system accompanied by a greater predisposition to ventricular and supraventricular arrhythmias, which in our study occurred from a median of 71.5 Lt of NaCl and with a utilization rate of 0.27-0.49 lt/min.

Conclusions: Fluid overload syndrome due to HoLEP is a rarely diagnosed entity that leads to the appearance of hyperchloremic metabolic acidosis after 90 minutes of enucleation that can appear in up to 23.6% of patients, with an average of fluids infused of NaCl from 43.9 liters and in prostate resections from 48 gr. The rapid identification of this fluid overload syndrome will allow negative assessments, administration of drugs such as diuretics and even the diagnosis of ischemia-reperfusion that can be harmful in patients with previous renal failure.

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KEYWORDS: Fluid Overload, Congestion, HoLEP Surgery, Metabolic Acidosis.

I. INTRODUCTION

Transurethral resection of the prostate (TURP) syndrome and holmium laser prostate enucleation (HoLEP) are two procedures used to treat benign prostatic hyperplasia (BPH), but they differ significantly in their approach and outcomes.

TURP is a traditional procedure that involves the removal of prostate tissue using a resection device inserted through the urethra. During TURP, irrigation is used to maintain a clear view of the surgical field and to remove tissue fragments. However, TURP is associated with an increased risk of complications, such as significant blood loss, the need for blood transfusions and electrolyte reabsorption syndrome.

HoLEP is a more advanced procedure that uses a holmium laser for prostatic enucleation. Instead of removing prostate tissue in fragments, HoLEP allows a complete enucleation of the prostatic lobe, which reduces the risk of recurrence of BPH symptoms. In addition, HoLEP is associated with less intraoperative blood loss and faster recovery compared to TURP.

Fluid overload syndrome (FOS) is a potentially serious complication that can occur during holmium laser enucleation of the prostate (HoLEP). This condition occurs when there is an excessive accumulation of fluid in the body, which can have significant hemodynamic consequences. Understanding the hemodynamic behavior of FSS in HoLEP is critical for early detection and appropriate management.

During HoLEP, continuous irrigation is used to maintain a clear view of the surgical field and facilitate removal of enucleated prostatic tissues. However, if the irrigation rate is too high or if excessive fluid absorption occurs, it can trigger FOS. This excess fluid can directly affect the patient's hemodynamics in several ways.

First, FOS can lead to an increase in intravascular volume, resulting in an expansion of circulating volume. This can cause an increase in cardiac preload, thereby increasing cardiac work and blood pressure. In addition, the increase in intravascular volume may trigger the release of natriuretic peptides, such as B-type natriuretic peptide (BNP), which contribute to the regulation of fluid and electrolyte balance in the body.

On the other hand, FOS can affect cardiac function by compromising myocardial contractility due to increased preload and volumetric overload. This may manifest as signs of heart failure, such as dyspnea, orthopnea, and pulmonary edema. Furthermore, increased intravascular pressure may predispose the patient to the cardiac arrhythmias development, such as atrial fibrillation, which may further complicate their hemodynamic condition.

In addition to the direct impact on the cardiovascular system, FOS can have adverse effects on renal and pulmonary

function, further contributing to altered hemodynamics. Fluid accumulation can compromise renal function, causing a decrease in glomerular filtration rate and an increase in serum creatinine levels. Besides, pulmonary edema secondary to FOS can compromise gas exchange and oxygenation, exacerbating dyspnea and hypoxemia.

Detection of FOS in HoLEP relies on a comprehensive assessment of patient hemodynamics, which may include monitoring of blood pressure, heart rate, oxygen saturation, BNP levels, and renal function. Additionally, attention to clinical signs of fluid overload, such as dyspnea, peripheral edema, and tachypnea, is critical. Early identification of FOS allows the implementation of appropriate therapeutic measures, such as fluid restriction, use of diuretics and optimization of ventilatory support, to prevent serious complications and improve patient outcomes.

II. MATERIALS AND METHODS

A descriptive, observational, single-center and retrospective study was performed in patients undergoing prostatic enucleation with Holmium laser (HoLEP) who developed water overload syndrome, between June 2023-2024 in the Hospital Juarez of Mexico. The demographic data and the dependent variables will be tested for normality according to the Kolmogorov-Smirnov test with Lilliefors correction. If the data are normally distributed, factorial ANOVA will be used for more than two independent samples where the Bonferroni test will be used post Hoc for the multiple pairwise comparison in a parametric manner, considering $p<0.05$ as statistically significant; if the data are not normally distributed, the Kruskal- Wallis test will be used for more than two independent samples where the Dunn's test will be used post hoc for the multiple pairwise comparison in a non-parametric way, considering $p<0.05$ as statistically significant.

By standard anesthetic procedure in the Hospital Juarez of Mexico, general anesthesia was administered in all patients with intravenous Fentanyl at a dose of 2mcg/kg, Propofol at 2mg/kg and Rocuronium at a dose of 0.60 mg/kg with latency of 4 minutes and ventilation with intermittent manual positive pressure with FIO2 100%. All patients underwent atraumatic laryngoscopy with endotracheal tubes of 7.5-8.5 Internal Diameter. They are connected to anesthetic circuit with mechanical ventilation in airway protective parameters in PCV-VG mode VT 6-8 ml/kg, RR 10-17 bpm, I:E 1:2.5, PEEP 6-8 according to PEEP/ARDSnet. Desflurane 0.8-1.2 MAC is used for anesthetic maintenance.

All patients were administered Hartman solution at a dose of 1 ml/kg with the aim of maintaining a MAP>65 mm Hg. In hypotension case (MAP <65 mm Hg), ephedrine 5mg IV was administered at bolus until normalization of mean arterial pressure (maximum 10 boluses). In case of bradycardia (HR <30 bpm) or bradycardia concomitant with hypotension, atropine 500 mcg IV DU was administered every 5 minutes until normalization of heart rate and mean arterial pressure (maximum 2 boluses).

Systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, heart rate, plethysmographic variability, pulse variation index by invasive monitoring with arterial line placed in left or right radial artery 22G as well as pH, partial pressure of arterial CO2, partial pressure of arterial O2, arterial bicarbonate, arteria base deficit, arterial lactate, sodium, potassium and chlorine by arterial blood by gasometry were registered during the different surgical times of HoLEP: (Start of Invasive Monitoring/Intubation, at 30 minutes, 60 minutes, 90 minutes, 120 minutes, 150 minutes and at the end of Invasive Monitoring/Extubation). Fluid overload syndrome is defined as the presence of any of these symptoms at the end of the procedure: Orthopnea (1-2 pillows), Jugular Venous Distention (6-9 cm), Crackles (<50%).

III.RESULTS

From the 142 files of patients who underwent HoLEP 2023-2024, 49 files/patients(34.51%) met the expected inclusion criteria. The remaining 49 files/patients, 100% were men with a median age 69 years (58-79 years), weight 62 kg (58-78 kg), height 1.67 m (1.55-1.74 m), BMI 22.1 kg/m^2 (21.7-25.8 kg/m^2) and body surface area 1.69 m^2 (1.61-1.71 m^2).

The main comorbidities were as follows: Systemic arterial hypertension 32(65.31%), Current alcoholism 30(61.22%), Current smoking 27(55.10%), Diabetes mellitus type II 21(42.86%), Presence of previous arrhythmias 11(22.45%) and previous prostate surgeries 7(14.29%).

The indications for HoLEP presented by the patients were: obstructive uropathy 45(91.84%), prostate >80 gr 43(87.76%), post-renal renal injury 33(67.35%), failure of medical treatment 28(57.14%), recurrent prostatitis 24(48.98%), urolithiasis 13(26.53%) and palliative treatment for obstructive prostate adenocarcinoma 4(8.16%).

Table 1. Epidemiological Baseline Characteristics of the Patients with Fluid Overload and HoLEP

Total number of patients	**Total**	**Fluid Overload**
	142	49
Epidemiological	*Median*	*Interquartile Range*
- Age	69 years	58-79 years
- Weight	62 kg	58-78 kg
- Size	1.67 m	1.55-1.74 m

- BMI	22.1 kg/m^2	21.7-25.8 kg/m^2
- Body Surface	1.69 m^2	1.61-1.71 m^2
Comorbidities		
- Systemic Arterial Hypertension	32 (65.31%)	
- Current Alcoholism	30 (61.22%)	
- Current Smoking	27 (55.10%)	
- Diabetes Mellitus type II	21 (42.86%)	
- Presence of previous Arrhythmias	11 (22.45%)	
- Previous Prostate Surgeries	7 (14.29%)	
Indications for HoLEP		
- Obstructive Uropathy	45 (91.84%)	
- Prostate >80 gr	43 (87.76%)	
- Postrenal Renal Injury	33 (67.35%)	
- Failure of medical treatment	28 (57.14%)	
- Recurrent prostatitis	24 (48.98%)	
- Urolithiasis	13 (26.53%)	
- Palliative (Adenocarcinoma)	4 (8.16%)	

Unless otherwise indicated, the numbers in the table are n (patients), %.
Baseline characteristics were defined at the time of study inclusion

Table 1. Epidemiological baseline characteristics of the patients with fluid overload syndrome and HoLEP.

At the beginning of Anesthesia, the hemodynamic variables: Systolic pressure 150 mmHg(146-154 mm Hg), Diastolic pressure 90.5 mmHg(87-94 mm Hg), Mean arterial blood pressure 110 mmHg(108-113 mm Hg), Heart rate 83 beats/minute(78-89 beats/minute), Pulse Variability 12.5% (10- 15) and Plethysmographic variability 13%(10-16%). As for the gasometrical variables: pH 7.40±0.02, CO2 partial pressure 32.94±1.80 mmHg, O2 partial pressure 81.05±2.32 mmHg, Bicarbonate 20.85±1.26 mmol/L, Base deficit -6.95±0.53 mmol/L, Arterial Sodium 134.68±1.41 mmol/L, Arterial Potassium 3.72±0.15 mmol/L, Arterial Chlorine 99.08±1.86 mmol/L, Arterial Lactate 1.41±0.22 mmol/L and Coefficient p50 27.29±0.23 mm Hg (Table 2).

Table 2. Hemodynamic and Gasometrical values at the beginning of Anesthesia

Hemodynamic Variables	*Median*	*Interquartile Range*
- Systolic Pressure (SBP) mm Hg	150	146-154
- Diastolic Pressure (DBP) mm Hg	90.5	87-94
- Mean Blood Pressure (MAP) mm Hg	110	108-113
- Heart rate (HR) beats/minute	83	78-89
- Pulse Variability (PVI)	12.5	10-15
- Plethysmographic Variability (PPV)	13	10-16
Gasometrical Variables	*Mean ± DE*	
- pH	7.40 ±0.02	
- CO2 Partial Pressure (pCO2) mm Hg	32.94 ±1.80	
- Partial O2 pressure (pO2) mm Hg	81.05±2.32	
- Bicarbonate (HCO3) mmol/L	20.85±1.26	
- Base Deficit (BD) mmol/L	-6.95±0.53	
- Arterial Sodium (NaS) mmol/L	134.68±1.41	
- Arterial Potassium (KaS) mmol/L	3.72±0.15	
- Arterial chlorine (ClaS) mmol/L	99.08±1.86	
- Arterial lactate (LacS) mmol/L	1.41±0.22	
- Coefficient p50 mm Hg	27.29±0.23	

Table 2. Hemodynamic and blood gas variables at the start of anesthesia in patients with fluid overload syndrome and HoLEP.

At 30 minutes after Holmium enucleation the hemodynamic variables: Systolic pressure 108 mm Hg(105-111 mm Hg), Diastolic pressure 61 mm Hg (55-64 mm Hg), Mean blood pressure 77 mm Hg(73-79 mm Hg), Heart rate 76.5 beats/minute(71-82 beats/minute), Pulse Variability 8%(5-

11%) and Plethysmographic variability 9%(6-12%). Gasometrical variables: pH 7.38±0.02, CO2 partial pressure 32.59±1.80 mmHg, O2 partial pressure 64.26±1.80 mmHg, Bicarbonate 19.34±1.26 mmol/L, Base deficit -5.45±0.53 mmol/L, Arterial Sodium 135.28±1.41 mmol/L, Arterial Potassium 3.32±0.15 mmol/L, Arterial Chlorine 101.37±1.95 mmol/L, Arterial Lactate 1.54±0.22 mmol/L and Coefficient p5027.29±0.99 mm Hg (Table 3). After statistical analysis only the progressive increase in SBP, DBP, MAP were found to be statistically significant (p<0.05).

Table 3. Hemodynamic and Gasometrical values at 30 minutes

Hemodynamic Variables	*Median*	*Interquartile Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	108	105-111	*<.001*	*<.001*
- Diastolic Pressure (DBP) mm Hg	61	55-64	*<.001*	*<.001*
- Mean Blood Pressure (MAP) mm Hg	77	73-79	*<.001*	*<.001*
- Heart rate (HR) beats/minute	76.5	71-82	*0.086*	*1*
- Pulse Variability (PVI)	8	5-11	*0.062*	*1*
- Plethysmographic Variability (PPV)	9	6-12	*0.083*	*1*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.38±0.02		*0.221*	*1*
- CO2 Partial Pressure (pCO2) mm Hg	32.59±1.80		*1*	*1*
- Partial O2 pressure (pO2) mm Hg	64.26±1.80		*0.022*	*0.465*
- Bicarbonate (HCO3) mmol/L	19.34±1.26		*0.325*	*1*
- Base Deficit (BD) mmol/L	-5.45±0.53		*0.081*	*1*
- Arterial Sodium (NaS) mmol/L	135.28±1.41		*0.138*	*1*
- Arterial Potassium (KaS) mmol/L	3.32±0.15		*0.065*	*1*
- Arterial chlorine (ClaS) mmol/L	101.37±1.95		*0.196*	*1*
- Arterial lactate (LacS) mmol/L	1.54±0.22		*0.464*	*1*
- Coefficient p50 mm Hg	27.29±0.99		*0.422*	*1*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 3. Hemodynamic and gasometrical variables at 30 minutes in patients with FOS and HoLEP.

At 60 minutes after Holmium enucleation the hemodynamic variables: Systolic pressure 116 mmHg(110-119 mm Hg), Diastolic pressure 63.5 mmHg(56.5-67 mm Hg), Mean arterial blood pressure 81 mmHg(76.3-83.3 mm Hg), Heart Rate 68.6 beats/minute(62.6-73.6 beats/minute), Pulse Variability 4.45%(1.7-7.2%) and Plethysmographic variability 5.2%(2.2-8.2%). Gasometrical variables: pH 7.34±0.02, CO2 partial pressure 32.24±1.80 mmHg, O2 partial pressure 61.61±1.80 mmHg, Bicarbonate 17.84±1.26 mmol/L, Base deficit -3.95±0.53 mmol/L, Arterial Sodium 135.78±1.41 mmol/L, Arterial Potassium 3.02±0.15 mmol/L, Arterial Chlorine 103.97±1.95 mmol/L, Arterial Lactate 1.76±0.22 mmol/L and Coefficient p50 26.59±0.98 mm Hg (Table 4). All hemodynamic changes occurring after 60 minutes are statistically significant (p<0.05) while gasometrical changes occurring after 60 minutes are statistically significant (p<0.05) except for arterial sodium.

Table 4. Hemodynamic and Gasometrical values at 60 minutes

Hemodynamic Variables	*Median*	*Interquartile Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	116	110-119	*<.001*	*<.001*
- Diastolic Pressure (DBP) mm Hg	63.5	56.5-67	*<.001*	*<.001*
- Mean Blood Pressure (MAP) mm Hg	81	76.3-83.3	*<.001*	*<.001*
- Heart rate (HR) beats/minute	68.6	62.6-73.6	*<.001*	*0.008*
- Pulse Variability (PVI)	4.45	1.7-7.2	*<.001*	*0.001*
- Plethysmographic Variability (PPV)	5.2	2.2-8.2	*<.001*	*0.002*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.34±0.02		*0.001*	*0.027*

- CO2 Partial Pressure (pCO2) mm Hg	32.24±1.80	*0.042*	*0.088*
- Partial O2 pressure (pO2) mm Hg	61.61±1.80	*<.001*	*0.007*
- Bicarbonate (HCO3) mmol/L	17.84±1.26	*0.001*	*0.027*
- Base Deficit (BD) mmol/L	-3.95±0.53	*<.001*	*0.009*
- Arterial Sodium (NaS) mmol/L	135.78±1.41	*0.138*	*1*
- Arterial Potassium (KaS) mmol/L	3.02±0.15	*<.001*	*0.002*
- Arterial chlorine (ClaS) mmol/L	103.97±1.95	*0.002*	*0.039*
- Arterial lactate (LacS) mmol/L	1.76±0.22	*0.024*	*0.514*
- Coefficient p50 mm Hg	26.59±0.98	*0.013*	*0.279*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 4. Hemodynamic and gasometrical variables at 60 minutes in patients with FOS and HoLEP.

At 90 minutes after Holmium enucleation the hemodynamic variables: Systolic pressure 125.5 mmHg (118.5-130 mmHg), Diastolic pressure 72.5 mmHg(66.5-75.5 mmHg), Mean arterial blood pressure 90.1 mmHg (85.8-92.8 mm Hg), Heart Rate 61.9 beats/minute(56.9-67.9 beats/minute), Pulse Variability 2.6%(0.6-5.1%) and Plethysmographic variability 3%(1.1-4.1%). Gasometrical variables: pH 7.31±0.02, CO2 partial pressure 31.89±1.80 mmHg, O2 partial pressure 59.96±1.80 mmHg, Bicarbonate 16.33±1.26 mmol/L, Base deficit -2.45±0.53 mmol/L, Arterial Sodium 136.38±1.41 mmol/L, Arterial Potassium 2.82±0.15 mmol/L, Arterial Chlorine 107.67±1.95 mmol/L, Arterial Lactate 1.99±0.22 mmol/L and Coefficient p50 25.52±0.97 mm Hg (Table 5). All hemodynamic/gasometrical changes at 90 minutes of the procedure are statistically significant (p<0.05).

Table 5. Hemodynamic and Gasometrical values at 90 minutes

Hemodynamic Variables	*Median*	*Interquartile Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	125.5	118.5-130	*<.001*	*<.001*
- Diastolic Pressure (DBP) mm Hg	72.5	66.5-75.5	*<.001*	*<.001*
- Mean Blood Pressure (MAP) mm Hg	90.1	85.8-92.8	*<.001*	*<.001*
- Heart rate (HR) beats/minute	61.9	56.9-67.9	*<.001*	*<.001*
- Pulse Variability (PVI)	2.6	0.6-5.1	*<.001*	*<.001*
- Plethysmographic Variability (PPV)	3.0	1.1-4.1	*<.001*	*<.001*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.31±0.02		*<.001*	*<.001*
- CO2 Partial Pressure (pCO2) mm Hg	31.89±1.80		*0.042*	*0.888*
- Partial O2 pressure (pO2) mm Hg	59.96±1.80		*<.001*	*<.001*
- Bicarbonate (HCO3) mmol/L	16.33±1.26		*<.001*	*<.001*
- Base Deficit (BD) mmol/L	-2.45±0.53		*<.001*	*<.001*
- Arterial Sodium (NaS) mmol/L	136.38±1.41		*0.002*	*0.035*
- Arterial Potassium (KaS) mmol/L	2.82±0.15		*<.001*	*<.001*
- Arterial chlorine (ClaS) mmol/L	107.67±1.95		*<.001*	*<.001*
- Arterial lactate (LacS) mmol/L	1.99±0.22		*<.001*	*<.001*
- Coefficient p50 mm Hg	25.52±0.97		*<.001*	*0.001*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 5. Hemodynamic and gasometrical variables at 90 minutes in patients with FOS and HoLEP.

At 120 minutes after Holmium enucleation the hemodynamic variables: Systolic pressure 137.5 mmHg (131.5-141 mmHg), Diastolic pressure 84.5 mmHg (77.5-87 mmHg), Mean blood pressure 102.08 mmHg (97.5-104.5 mmHg), Heart Rate 54.8 beats/minute (49.6-60.6 beats/minute), Pulse Variability 1.55%(1-3.6%) and Plethysmographic variability 2.3%(0.6-3.6%). Gasometrical variables: pH 7.28±0.02, CO2 partial pressure 31.54±1.80 mmHg, O2 partial pressure 57.31±1.80 mmHg, Bicarbonate 14.82±1.26 mmol/L, Base deficit -0.95±0.53 mmol/L, Arterial Sodium 137.88±1.41 mmol/L, Arterial Potassium 2.72±0.15 mmol/L, Arterial Chlorine 112.57±1.95 mmol/L, Arterial Lactate 2.32±0.22 mmol/L and Coefficient

p50 24.04±1.05 mm Hg (Table 6). All hemodynamic/gasometrical changes at 120 minutes of the procedure are statistically significant (p<0.05).

Table 6. Hemodynamic and Gasometrical values at 120 minutes

Hemodynamic Variables	*Median*	*Interquartile Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	137.5	131.5-141	*0.001*	*0.026*
- Diastolic Pressure (DBP) mm Hg	84.5	77.5-87	*0.007*	*0.048*
- Mean Blood Pressure (MAP) mm Hg	102.08	97.5-104.5	*0.001*	*0.016*
- Heart rate (HR) beats/minute	54.8	49.6-60.6	*<.001*	*<.001*
- Pulse Variability (PVI)	1.55	1-3.6	*<.001*	*<.001*
- Plethysmographic Variability (PPV)	2.3	0.6-3.6	*<.001*	*<.001*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.28±0.02		*<.001*	*<.001*
- CO2 Partial Pressure (pCO2) mm Hg	31.54±1.80		*0.042*	*0.888*
- Partial O2 pressure (pO2) mm Hg	57.31±1.80		*<.001*	*<.001*
- Bicarbonate (HCO3) mmol/L	14.82±1.26		*<.001*	*<.001*
- Base Deficit (BD) mmol/L	-0.95±0.53		*<.001*	*<.001*
- Arterial Sodium (NaS) mmol/L	137.88±1.41		*<.001*	*<.001*
- Arterial Potassium (KaS) mmol/L	2.72±0.15		*<.001*	*<.001*
- Arterial chlorine (ClaS) mmol/L	112.57±1.95		*<.001*	*<.001*
- Arterial lactate (LacS) mmol/L	2.32±0.22		*<.001*	*<.001*
- Coefficient p50 mm Hg	24.04±1.05		*<.001*	*<.001*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 6. Hemodynamic and gasometrical variables at 120 minutes in patients with FOS and HoLEP.

At 150 minutes after Holmium enucleation the hemodynamic variables: Systolic pressure 141.5 mmHg(137-149 mm Hg), Diastolic pressure 90.5 mmHg(88-94 mm Hg), Mean blood pressure 107.67 mmHg(105-110 mm Hg), Heart Rate 46.5 beats/minute(40.5-51.5 beats/minute), Pulse Variability 1%(0.6-3.1%) and Plethysmographic variability 2%(1-3.1%). Gasometrical variables: pH 7.26±0.02, CO2 partial pressure 31.18±1.80 mmHg, O2 partial pressure 55.66±1.80 mmHg, Bicarbonate13.31±1.26 mmol/L, Base deficit 0.55±0.53 mmol/L, Arterial Sodium 139.38±1.41 mmol/L, Arterial Potassium 2.62±0.15 mmol/L, Arterial Chlorine 117.88±1.95 mmol/L, Arterial Lactate 2.7±0.22 mmol/L and Coefficient p50 22.23±1.0 mmHg (Table 7). All hemodynamic/gasometrical changes at 150 minutes of the procedure are statistically significant (p<0.05).

Table 7. Hemodynamic and Gasometrical values at 150 minutes

Hemodynamic Variables	*Median*	*Interquartile Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	141.5	137-149	*0.046*	*0.046*
- Diastolic Pressure (DBP) mm Hg	90.5	88-94	*0.045*	*0.03*
- Mean Blood Pressure (MAP) mm Hg	107.67	105-110	*0.018*	*0.011*
- Heart rate (HR) beats/minute	46.5	40.5-51.5	*<.001*	*<.001*
- Pulse Variability (PVI)	1	0.6-3.1	*<.001*	*<.001*
- Plethysmographic Variability (PPV)	2	1.0-3.1	*<.001*	*<.001*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.26±0.02		*<.001*	*<.001*
- CO2 Partial Pressure (pCO2) mm Hg	31.18±1.80		*<.001*	*0.001*
- Partial O2 pressure (pO2) mm Hg	55.66±1.80		*<.001*	*<.001*
- Bicarbonate (HCO3) mmol/L	13.31±1.26		*<.001*	*<.001*
- Base Deficit (BD) mmol/L	0.55±0.53		*<.001*	*<.001*
- Arterial Sodium (NaS) mmol/L	139.38±1.41		*<.001*	*<.001*
- Arterial Potassium (KaS) mmol/L	2.62±0.15		*<.001*	*<.001*

- Arterial chlorine (ClaS) mmol/L	117.88±1.95	*<.001*	*<.001*
- Arterial lactate (LacS) mmol/L	2.7±0.22	*<.001*	*<.001*
- Coefficient p50 mm Hg	22.23±1.0	*<.001*	*<.001*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 7. Hemodynamic and gasometrical variables at 150 minutes in patients with FOS and HoLEP.

At the end of anesthesia hemodynamic variables: Systolic pressure 161 mmHg(155-167 mmHg), Diastolic pressure 98.5 mmHg(93.5-102.5 mmHg), Mean blood pressure 119.3 mmHg(116-122.3 mmHg), Heart Rate 34.9 beats/minute(29-42.4 beats/minute), Pulse Variability 1%(0.8-2.3%) and Plethysmographic variability 2%(0.8-2.8%). Gasometrical variables: pH 7.25±0.02, CO2 partial pressure 30.83±1.80 mmHg, O2 partial pressure 53.0±1.80 mmHg, Bicarbonate 11.80±1.26 mmol/L, Base deficit 2.05±0.53 mmol/L, Arterial Sodium 140.88±1.41 mmol/L, Arterial Potassium 2.52±0.15 mmol/L, Arterial Chlorine 123.18±1.95 mmol/L, Arterial Lactate 3.09±0.22 mmol/L and Coefficient p50 20.35±1.04 mm Hg (Table 8). After statistical analysis all the hemodynamic and gasometrical values are statistically significant until SDP, DBP, MAP with p<0.05.

Table 8.

Hemodynamic Variables	*Median*	*Interquarti* **Hemodynamic and Gasometrical values at End of Anesthesia** *le Range*	*p **	*p adjusted +*
- Systolic Pressure (SBP) mm Hg	161	155-167	*0.069*	*1*
- Diastolic Pressure (DBP) mm Hg	98.5	93.5-102.5	*0.008*	*0.176*
- Mean Blood Pressure (MAP) mm Hg	119.3	116-122.3	*0.049*	*1*
- Heart rate (HR) beats/minute	34.9	29-42.4	*<.001*	*<.001*
- Pulse Variability (PVI)	1	0.8-2.3	*<.001*	*<.001*
- Plethysmographic Variability (PPV)	1	0.8-2.8	*<.001*	*<.001*
Gasometrical Variables	*Mean ± DE*		*p ***	*p adjusted +++*
- pH	7.25±0.02		*<.001*	*<.001*
- CO2 Partial Pressure (pCO2) mm Hg	30.83±1.80		*<.001*	*0.001*
- Partial O2 pressure (pO2) mm Hg	53.0±1.80		*<.001*	*<.001*
- Bicarbonate (HCO3) mmol/L	11.80±1.26		*<.001*	*<.001*
- Base Deficit (BD) mmol/L	2.05±0.53		*<.001*	*<.001*
- Arterial Sodium (NaS) mmol/L	140.88±1.41		*<.001*	*<.001*
- Arterial Potassium (KaS) mmol/L	2.52±0.15		*<.001*	*<.001*
- Arterial chlorine (ClaS) mmol/L	123.18±1.95		*<.001*	*<.001*
- Arterial lactate (LacS) mmol/L	3.09±0.22		*<.001*	*<.001*
- Coefficient p50 mm Hg	20.35±1.04		*<.001*	*<.001*

** p statistically significant with Kruskal-Wallis test (p<0.05); + p adjusted significant with Dunn-Bonferoni test (p<0.05); ** p statistically significant with Factorial ANOVA test (p<0.05); ++ p adjusted p significant with Dunn-Bonferoni test (p<0.05)*

Table 8. Hemodynamic and gasometrical variables at End of Anesthesia in patients with FOS and HoLEP.

Table 9. Intraoperative and Postoperative Surgical/Anesthetic Complications.

Intraoperative Surgical Complications	*N (%)*
- Hemostatic complications	43(87.76%)
- Capsular perforation	40(81.63%)
- Prostate discordant size >100 gr.	37(75.51%)
- Tissue Morcellator malfunction	33(67.35%)
- High density of enucleated prostate tissue	28(57.14%)

Postoperative Surgical Complications	*N (%)*
- Presence of urinary retention with clots	29(59.18%)
- Need for transfusion in hospitalization	6(12.24%)
- Prolonged hospitalization (>3 days)	3(6.12%)
Intraoperative Anesthetic Complications	*N (%)*
- Hyperchloremic Metabolic Acidosis	43(87.76%)
- Arterial hypernatremia (>135 mmol/L)	41(83.67%)
- Arterial hyperchloremia (>115 mmol/L)	37(75.51%)
- Arterial hypocalcemia (<1.2 mmol/L)	33(67.35%)
- Hypokalemia (<3 mmol/L)	31(63.27%)
- Sinus Bradycardia (<60 beats/minute)	30(61.22%)
- Hyperlactatemia (>2 mmol/L)	28(57.14%)
- Isolated ventricular extrasystoles (<5 per minute)	26(53.06%)
- Need for diuretics overload (1 dose)	23(46.94%)
- Need for use of atropine (1 dose)	18(36.73%)
- Need for use of ephedrine (1 dose)	11(22.45%)
- Fluid overload to extubation	5(10.20%)
Postoperative Anesthetic Complications	*N (%)*
- Orthopnea in PACU	48(97.96%)
- Arterial hypertension in PACU	48(97.96%)
- Requirement of arterial blood gas measurements in PACU	47(95.92%)
- Bilateral crepitant rales in PACU	40(81.63%)
- Persistent hyperlactatemia in PACU	38(77.55%)
- Need for diuretic use (2nd dose) due to overload in PACU.	35(71.43%)
- Need for tranexamic acid administration in PACU	30(61.22%)
- Need for bicarbonate administration in PACU	28(57.14%)
- Jugular Ingurgitation at the end of the surgical procedure	23(46.94%)
- Isolated ventricular extrasystoles in PACU.	21(42.86%)
- Non Invasive Mechanical Ventilation (High Flow Nasal Prongs)	19(38.78%)
- Non Invasive Mechanical Ventilation (CPAP)	11(22.45%)
- Transfusion requirement (1 RBC)	8(16.33%)
- Need for reintervention (<1 hour)	5(10.20%)
- Admission to Intensive Care Unit	3(6.12%)

Unless otherwise indicated, the numbers in the table are n (patients), %. Intraoperative complications were obtained at the time of surgery by the urology staff. Anesthetic complications were documented on the patients' anesthesia record

Table 9. Surgical/Anesthesia complications in patients with FOS and HoLEP.

The intraoperative surgical complications: Hemostatic complications 43(87.76%), Capsular perforation 40(81.63%), Prostate discordant size >100gr 37(75.51%), Tissue Morcellator malfunction 33(67.55%), High density of enucleated prostate tissue 28(57.14%); Postoperative surgical complications: Presence of urinary retention with cloths 39(59.18%), Need for transfusion in hospitalization 6(12.24%), Prolonged hospitalization (>3days) 3(6.12%).
The intraoperative anesthesia complications: Hyperclorhemic Metabolic Acidosis 43(87.76%), Hypernatremia >135mmol/L 41(83.67%), Hyperchloremia >115mmol/L 37(75.51%), Hypocalcemia <1.2mmol/L 33(67.35%), Hypokalemia <3mmol/L 31(63.27%), Sinus Bradycardia 30(61.22%), Hyperlactatemia 28(57.14%), Isolated Ventricular Extrasystoles 26(53.06%), Need for administration of Furosemide 23(46.94%), Need for use of atropine 18(36.73%), Need for use of ephedrine 11(22.45%), Fluid Overload at extubation 5(10.20%); Postoperative anesthesia complications: Orthopnea 48(97.96%), Hypertension 48(97.96%), Arterial Blood Gas in PACU 47(95.92%), Bilateral crepitant rales 40(81.63%), Persistent Hyperlactatemia 38(77.55%), Need for Furosemide (2^{nd} dose) 35(71.43%), Need for Tranexamic Acid 1gr dose 30(61.22%), Need for Bicarbonate 44.5meq/dose administration 28(57.14%), Jugular Ingurgitation 23(46.94%), Isolated ventricular extrasystoles 21(42.86%), Non Invase High Flow Nasal Prongs 19(38.78%), Non Invasive CPAP 11(22.45%), Transfusion requirement 1 RBC 8(16.33%); Need for Reintervention <1hour 5(10.20%) and Admission to ICU 3(6.12%).

IV. DISCUSSION

Transurethral resection of the prostate syndrome with glycine (electrolyte-free, hypotonic) uptake results in acute hypo-osmolarity causing fluid to enter the intracellular space

with risk of hemolysis, neuronal disruption,cardiac failure, pulmonary edema and renal failure. TUR syndrome with 0.9% saline absorption manifests as iso-osmolar overhydration with plasma volume expansion resulting in cardiac decompensation and acute pulmonary edema.

During HoLEP, laser energy is used instead of electrical energy. The penetration depth does not exceed 0.5-1 mm, resulting in more superficial tissue perforation compared to deep resection caused by a bipolar resection loop. The risk of fluid absorption increases with the depth of resection and the number of open venous sinuses.

In this cohort of patients with volume overload, they respond to myocardial fiber strain to a variable degree by increasing cardiac output and stroke volume until dysfunction due to myocardial insufficiency occurs. Myocardial depression in turn produces microvascular dysfunction with alterations in the regulatory functionsofthe endothelium. This behavior is demonstrated by changes in systolic, diastolic, and mean blood pressure that compensate for fluid overload within the first 90 minutes of surgery. Few studies have reported theclinical outcomes of patients undergoing HoLEP, being the hemodynamic behavior variables the least described.

Reflex vasoconstriction, especially in the splanchnic and musculocutaneous territory, allows distribution to thebenefit of the cerebral, coronary and hepatic circulation. The renal circulation benefits directly but suffers subsequently from vasoconstriction when blood losses reach 10-30% of the circulating blood volume, evident in a statistically significant way by the changes that occur both in the pulse variability index and in the plethysmographic variability after 90 minutes. It is in this way that the nervous system compensates for the hemorrhage by increasing mean arterial pressure and decreasing resistance to venous return to lead to a pseudo-normalization of cardiac output with decreased heart rate.

The microcirculatory affectation caused by arterial pressure in turn decreases capillary bed flows producing local ischemia with direct changes in arterial lactate that begin after 60 minutes but that show evidence of tissue hypoxia after 90 minutes, being statistically significant. The phenomenon of lack of flow due to persistent hypoperfusion produces an ischemic event in which the accumulation of reactive forms of oxygen and acid freeradicals gradually decreases the pH after 60 minutes, but significantly from 90 minutes until the end of the surgical procedure, leading to blood acidosis.

The initial management of this imbalance at the microcirculatory level and acidosis is performed with the infusion intravenous fluids, however, when volume overload syndrome is produced by direct reabsorption of sodium chloride through the prostatic beds during HoLEP.

The analysis of electrolyte behavior showed an increase in serum sodium after 60 minutes but causing hypernatremia after 90 minutes, with a significant change of 8 mmol/L during the surgical procedure. Likewise,there is an increase in serum chloride from 60 minutes, but which causes significant hyperchloremia with a maximum change of 26 mmol/L causing hyperchloremic acidosis.

During metabolic acidosis, a reduction in bicarbonate concentration occurs primarily after 60 minutes, but clinically evident at 90 minutes as a compensatory phenomenon in response to changes in the partial pressure of carbon dioxide. However, in our study, when the patient was under general anesthesia balanced with ventilatory protective parameters with monitoring of exhaled carbon dioxide (ETCO2) to generate changes in the respiratory rate to maintain CO2 in adequate ranges.

If this fluid infusion is continued through prostatic reabsorption of sodium chloride, cardiac failure is produced by activation of the sympathetic nervous system accompanied by a greater predisposition to ventricular and supraventricular arrhythmias, which in our study occurred at a median of 71.5 Lt of NaCl and with a utilizationrate of 0.27-0.49 lt/min.

It is worth mentioning that hyperchloremic metabolic acidosis, as in the case of our study, occurs at a cut-off point of 0.79 Cl/Na index. This index is associated with an elevation of lactate due to dysoxia or hypoperfusionand has been associated with a high risk of death at 30 days; however, more studies with a greater number of patients are required to improve the degree of evidence.

Cardiac performance is maintained for a short time due to increased contractility and decreased heart rate. Therefore, assessing the previous functional status of the heart and specifically of the left ventricle is a key determinant in the prognosis of these patients with acute volume overload syndrome. The patient's previous pathology plays a decisive role during cardiac injury, especially in those pathologies (idiopathic cardiomyopathy) with high heart rates or the presence of sporadic cardiac arrhythmias, silent diastolicdysfunction, and a deteriorated functional class.

In 2022 Solts et al. published a study referring to other risk factors for the development of complications duringHoLEP such as bladder distension and increased intravesical pressure. These risk factors are not always documented and due to the characteristics of the design they were not described in our study.

V. CONCLUSION

Fluid Overload Syndrome (FOS) due to HoLEP is an underdiagnosed entity that leads to the appearance of hyperchloremic metabolic acidosis after 90 minutes of enucleation, which can appear in up to 23.6% of patients, with a mean of NaCl infused fluids from 43.9 l and in prostate resections from 48 grams.

The rapid identification of this fluid overload syndrome will allow the performance of negative balances, the administration of drugs such as diuretics and even the diagnosis of ischemia-reperfusion, which can be harmfulin

patients with previous renal failure.

The limitations of our study included a small sample size, etiologies heterogeneity of the patients undergoing HoLEP as well as the calibration parameters of the arterial blood gas meter. The works published to date present statistically significant and coincident results in the line of thought however there is no such large and detailed previous casuistry in the literature. Larger population samples including this group of patientswith HoLEP are required to achieve reference and therapeutic values.

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