Bioimpedance Estimation Of Volume And Hemodynamic Changes During Transurethral Resection Of Prostate (TURP)

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Citation

A Sherman, Y Frinerman, D Zabeeda, S Ezra, A Sidi, R Zimlichman, T Ezri. *Bioimpedance Estimation Of Volume And Hemodynamic Changes During Transurethral Resection Of Prostate (TURP)*. The Internet Journal of Anesthesiology. 2002 Volume 7 Number 1.

Abstract

Objective: During TURP volume and hemodynamic changes occur due to bladder irrigation.

Methods: Hemodynamics, total body water (TBW) and plasma sodium were monitored using bioimpedance in 36 patients undergoing TURP under spinal anesthesia (SA).

Results: Following SA, mean arterial pressure (MAP), heart rate (HR) and systemic vascular resistance (SVR) decreased vs. the preoperative values (88±8 vs. 106.4 ±12 mmHg, 66± 12 vs. 77.7 ±11 beats/minute, and 880±130 vs. 1100±180 dynn.sec.cm-5 - p<0.05). Postoperatively, MAP was lower than preoperatively and higher than postspinal (99.6±14.6 vs. 106.4±12 and 88.8±8 - p<0.05). The postoperative HR was lower than preoperatively (68.2±14.3 vs. 77.6±11 - p<0.05), cardiac index (CI) decreased vs. preoperative and postspinal values (2.40±0.80 vs. 3.04±0.86 and 2.98±0.7 - p<0.05). The SVR was lower after SA vs. preoperative and postoperative values (880±130 vs. 1100±180 and 1220±120 - p<0.05). TBW did not change.

Conclusions: CI and HR decreased following TURP. Serum sodium was lower postoperatively.

INTRODUCTION

Large amounts of glycine, an electrolyte-free irrigating fluid, used in TURP are absorbed into the blood stream and may induce circulatory overload, toxic effects (including neurological signs), dilution of electrolytes and proteins and interference with renal function ([1]). The diagnosis of TURP syndrome is based upon clinical signs and laboratory demonstration of dilutional electrolyte disturbances ([1]). Thoracic bioimpedance (impedance cardiography) is based upon the principle of a change in transthoracic electrical resistivity, which occurs during ejection of blood into the thoracic ascending aorta ([2]). The more water in the thorax, the better the conductivity to electrical flow and the lower its resistance ([2]). Impedance cardiography has been proposed as a simple and readily reproducible noninvasive technique for the determination of cardiac output, systemic vascular resistance and thoracic fluid content ([2]).

In this study we used the bioimpedance method for hemodynamic monitoring of the patients undergoing TURP under spinal anesthesia.

METHODS

Thirty-six patients aged 50-70 years were enrolled in this prospective study. Excluded were patients with a documented ejection fraction of less than 50%, renal failure, patients who received diuretic treatment, those who had peripheral edema and those who refused SA, or those in whom SA was contraindicated. Before performing SA, patients were connected to the bioimpedance monitor (NICa S-2001 Noninvasive Medical LTD, Israel) for hemodynamic and total body water (TBW) measurements. Patients were also monitored with ECG, pulse oximetry, noninvasive blood pressure and axillary temperature measurements. Two upper limb veins were cannulated with large bore cannulae (14 or 16G) for administration of fluids and blood sampling. Before performing SA, 500 ml of lactated Ringer's solution were infused over 20 minutes, followed by 2-4 $ml.Kg^{-1}$

.hour $^{-1}$. Oxygen was administered throughout the procedure. A decrease in systolic blood pressure of more than 30% for over 5 minutes was treated with an intravenous bolus of 5 mg of ephedrine. Glycine 1.5% was used for bladder irrigation. Intravesical pressures were not measured during the procedure.

ANESTHESIA

Patients were premedicated with oral diazepam (0.1mg.kg $^{-1}$) one hour before surgery. Spinal anesthesia was performed in lateral position at L2-L3, with a 27G pencil point needle (Whitacre). Heavy bupivacaine (12.5 mg) was subsequently injected into the spinal space. Immediately after SA, the patient was placed in lithotomy position and the legs were elevated on stirrups. No other medication (sedatives, opiates) was given during surgery. If SA failed or was insufficient for surgery, general anesthesia was added and the patient was excluded from the study.

MEASUREMENTS

Mean arterial blood pressure and HR were recorded every 3 minutes. Cardiac index and SVR were measured with the bioimpedance monitor 3 times in each patient: before SA and the fluid bolus, after SA (before starting the operation, with the legs on the stirrups) and at the end of surgery after lowering the legs from the stirrups (before the glycine was changed over for normal saline as for postoperative irrigation).

Total body water was measured with the bioimpedance method as well, prior to SA, after SA and at the end of surgery.

The bioimpedance apparatus we used, was patented in both USA (Patent # US5469856) and Europe (Patent # EP0575984). The accuracy of the hemodynamic measurements performed with this machine compared to the thermodilution technique has been previously validated by, in patients undergoing coronary artery bypass grafting ($_3$).

Electrolytes (sodium and potassium), blood glucose and hemoglobin were also measured at the same time points, using a blood gas machine (Chiron Diagnostics 865, Chiron Corporation, East Walpole, Ma, USA). The total volume of intravenous and infused irrigation fluids was recorded.

The study was undertaken after obtaining approval of the Institutional Ethics Committee. Written informed consent was obtained from each patient.

STATISTICAL ANALYSIS

The paired t-test method was used to statistically compare the mean values of the variables at various phases of the measurements. A p 0.05 was considered statistically significant.

RESULTS

The mean age was 66±12 years, mean weight was 72±12 Kg, mean height was 176±9 cm, and the mean duration of surgery was 52±19 minutes. Estimated blood loss was less than 300ml in each patient. No patient was excluded because of failure of SA. The upper sensory level of SA was T8±3 segments. Blood replacement therapy or ephedrine boluses were not needed in any of the participating patients. The mean total amount of intravenous fluids infused was 1.6 ± 0.4 L and that of irrigating fluids was 12.9 ± 6.6 L. The largest volume of irrigating fluid (25 liters) was recorded in patients who were operated on for more than 105 minutes. Serum potassium, glucose and hemoglobin did not differ significantly between the beginning and end of surgery. There was a slight increase in postoperative TBW (41.9 L) compared to the preoperative and postspinal values (41.7 L and 41.6 L respectively) in patients who received more than 20 liters of irrigating fluid, but the difference was not statistically significant. Serum sodium was lower (138±3mEq.L $^{-1}$ versus 143±2 and 142±3) postoperatively than preoperatively and after SA (P=0.0029).

One case sustained severe, acute postoperative hyponatremia (108 mEq.L $^{-1}$). Two other patients had sodium values of 116 and 117 respectively. All these patients received more than 20 liters of irrigation fluid, were operated on for more than 100 minutes and suffered from CNS manifestations (confusion, somnolence), but remained hemodynamically stable and had no signs of pulmonary congestion. Patients were managed with fluid restriction, administration of 0.9% saline solution, and 10 mg of furosemide intravenously. The sodium levels returned to normal within 6-8 hours.

Table 1 summarizes the hemodynamic measurements recorded before SA, after SA with the legs on the stirrups and at the end of surgery, with the legs lowered from the stirrups. Folowing SA, there was a significantly decrease in MAP, HR and SVR,

compared to the preoperative values (p<0.05). Following surgery, MAP was lower compared to the preoperative period and increased compared to the postspinal period (p<0.05). The postoperative HR was lower than preoperatively ($p<0.05$) whereas CI decreased significantly compared to the preoperative and postspinal values ($p<0.05$). Cardiac index decreased by 20% at the end of the procedure compared to the preoperative value. SVR was higher both preoperatively and postoperatively than immediately after SA. The clinical manifestation, hemodynamics, water balance and electrolyte data of the 3 patients who developed postoperative hyponatremia is presented in table 2.

Figure 1

Table 1. Comparison of preoperative, postspinal and postoperative hemodynamic measurements

Variable	Preoperative (1)	**Postspinal (2)**	**Postoperative (3)**	P value
Mean Arterial Pressure	106.4±12[1]	88±8	99.6±14.6	<0.05 for 2 vs 1 and 3 <0.05 for 3 vs 1
Heart Rate	77.6±11[2]	66±12	68.2±14.3	<0.05 for 3 and 2 vs 1
Cardiac Index	3.04±0.86[3]	2.98±0.7	2.40±0.80	<0.05 for 3 vs 1 and 2
Systemic Vascular Resistance	1100±180[4]	880±130	1220±120	<0.05 for 2 vs 1 and 3

Numbers represent mean ± SD and expressed in: [1] mmHg, [2] beats/minute, [3] Liter/minute/m^2, [4] dynes.sec.cm^{-5} p 0.05 was considered significant.

Figure 2

Table 2. Data of the 3 patients who developed postoperative hyponatremia

Variable	Patient number	Preoperative	Postspinal	Postoperative
Mean arterial pressure[1]	1 2 3	110 108 98	86 84 88	106 105 96
Heart rate[2]	1 2 3	84 68 80	72 62 74	92 66 70
Cardiac index[3]	1 2 3	3.3 3.3 3.6	3.2 3.1 3.4	3 3 3.3
Systemic vascular resistance[4]	1 2 3	1210 1190 1070	950 960 1010	1280 1270 1150
Total body water*	1 2 3	41.7 41.8 41.7	41.7 41.7 41.6	42.2 41.8 41.9
Serum sodium**	1 2 3	139 142 139	138 137 139	108 116 117
Amount of irrigating fluids*	1 – 25.2 2 - 23.9 3 - 24.5			
Neurological signs	1 2 3	Somnolence , confusion		

Numbers are expressed in: [1] mmHg, [2] beats/minute, [3] Liter/minute/m^2, [4] dynes.sec.cm^{-5} *liters, and **mEqv.L^{-1} .

DISCUSSION

We evaluated the changes in TBW, plasma sodium and hemodynamic variables during TURP performed under SA. Although a transient hypervolemia may occur during the first 20 minutes of absorption of irrigating fluids, this is usually followed later on by hypovolemia and hypotension caused by translocation of the absorbed fluids from plasma to the interstitial space and by the glycine-induced osmotic diuresis [4]. This may explain why the postoperative TBW increased only slightly compared to the preoperative values.

As shown by our results, only the patients with severe hyponatremia (Na<120 mEq.L^{-1}) were symptomatic. Severe hyponatremia was associated with the use of more than 20 L of irrigating glycine and with surgey lasting more than 100 minutes. As a routine of our department, severe hyponatremia was treated with fluid restriction, administration of 0.9% NaCl and a small dose of furosemide.

The mechanism behind the hemodynamic changes observed in patients who develop TURP syndrome is multifactorial, possibly involving the glycine's direct cardiac depressant effect and hypovolemia (which follows a short period of hypervolemia), caused by ostmotic diuresis and translocation of intravascular fluid to the interstitium [5,6]. In a Doppler ultrasonographic study of hemodynamics during intravenous infusion of glycine in healthy volunteers, Nilsson et al found a decrease in HR and cardiac output (CO) and an increase in MAP indicating a higher SVR [7]. However, we cannot blame the glycine for these effects, as we did not measure the serum levels of glycine or its metabolites.

We recorded similar hemodynamic changes except for a decrease instead of an increase in MAP. The decrease in MAP despite a slightly elevated SVR may be explained by a significant drop in CO caused by SA and/ or by translocation of intravascular fluid to the interstitium [4]. The measurements performed immediately after SA confirmed our hypothesis. Also, the arterial vasodilation produced by SA may have ameliorated the increase in SVR that was a response to the drop in CO. Spinal anesthesia may affect hemodynamics by several mechanisms [8]. The venodilation caused by SA may decrease the preload and thus, the CO. Cardiac output is also decreased by bradycardia which has multiple etiologies: a decrease in venous return to the right atrium (the “reverse Bainbridge” reflex), an imbalance between the sympathetic and parasympathetic system, a decrease in adrenal catecholamine secretion if the spinal block is higher than T4 and inhibition of cardioacceleratory nerves if the spinal block is involving these fibers (T1-T4).

Both the decrease in preload to the heart and arterial vasodilation, are attributed to preganglionic sympathetic neural blockade. The amount of hypotension is directly related to the extent of sympathetic blockade. The further drop in CO at the end of surgery, despite a higher HR and SVR, suggest that the hemodynamic changes cannot be attributed solely to SA. It would be helpful to have a central venous or a pulmonary artery catheter in place for concomitant preload measurements. Because invasive hemodynamic monitoring is not routinely used during SA, we have chosen to use noninvasive monitoring in these awake patients.

Impedance cardiography enables assessment and management of thoracic fluid status, cardiac output and its derivatives by continuous, noninvasisve measurements ([2]).

In our experiment, points of time for bioimpedance measurements were chosen as points in which the patient was in a hemodynamic steady state. Hemodynamic evaluation should be performed in steady state in order to receive physiologically interpretable data. Continuous hemodynamic monitoring during surgery will supply data of various aspects. These would reflect various stages of anesthesia, blood loss, effects of various medications given, etc. In such setup these data may be more confusing than contributing. The advantage of measurements in points of time when the patient is in steady state is that “clean “ results, reflecting physiologic changes are collected.

The thoracic bioimpedance method has also been used to assist in determining an adequate dosage regimen of inotrope infusions in patients with Class III and IV heart failure, by immediate noninvasive display of CO ([9]).

In patients with dual-chamber pacemakers, cardiac output can vary significantly by altering the atrio-ventricular (AV) delay. With the beat-to-beat stroke volume monitoring available with thoracic bioimpedance, CO can be evaluated at a wide range of AV delays in the pacemaker clinic, within minutes ([10]).

While this would not be a replacement for myocardial biopsy, impedance cardiography monitoring can serve as a valuable noninvasive adjunct in postoperative diagnosis of early rejection following heart transplantation ([11]). The accuracy of the bioimpedance measurements of CO and its derivatives compared to the thermodilution method has been validated in patients undergoing coronary artery grafting ([3]), in critical care patients ([12]), in patients suffering from preeclampsia ([13]), and in patients with severe blunt trauma ([14]). The bioimpedance method also enables simultaneous measurements of the total body water and compartmental water distribution ([15]).

Noninvasive hemodynamic monitoring with the bioimpedance method offers several advantages. First, it obviates the complications related to the use of pulmonary artery catheters, such as: pneumothorax, pulmonary infarction, air embolism, infection, etc. It may be applied without causing discomfort to awake patients during surgeries under regional anesthesia. In critical care settings, it allows for independent nurse care as opposite to the use of pulmonary artery catheter, which requires the active intervention of a physician for insertion and measurements.

Thoracic bioimpedance measurements may not be reliable in certain circumstances such as extremely large amounts of thoracic fluid (i.e. in severe pulmonary edema which may interfere with the impedance signal. ([2]). Its use is also limited in uncooperative patients or those with excessive movement ([2]) and in hemodynamically significant valvular disease or severe deformation of the chest wall.

By using thoracic bioimpedance monitoring, we found that systemic vascular resistance increased and cardiac index decreased significantly following transurethral resection of prostate, without a significant change in total body water.

We believe that thoracic bioimpedance monitoring may help understand the complexity of the hemodynamic changes associated with transurethral resection of prostate and may improve our ability for diagnosis and treatment of TURP syndrome.

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References

1. Hahn RG. The transurethral resection syndrome. Acta Anaesthesiol Scand
1991;35:557-67.

2. Bernstein DP. Noninvasive Cardiac Output Measurement. In: Shoemaker
WC, Ayres SM, Grenvik A, Holbrook PR, Thompson CW. Textbook of Critical
Care, 2nd Edition. Philadelphia: W. B. Saunders Company, 1989, pp 159-185.
3. Cohen A, Frinerman E, Katz M, Ezra S, Dotan A, Weisenberg M, Schachner
A. Validity of bioimpedance hemodynamic measurements during coronary
artery bypass grafting (CABG). Isr J Med Sci. 1996;32:966.
4. Hahn RG. Fluid and electrolyte dynamics during development of the TURP
syndrome. Br J Urol 1990;66:79-84.
5. Hahn RG. Natriuresis and "dilutional" hyponatremia after infusion of glycine 1.5%.
J Clin Anesth 2001;13:167-74.
6. Hahn RG, Zhang W, Rajs J. Pathology of the heart after overhydration with glycine
solution in the mouse. APMIS 1996;104:915-20.
7. Nilsson A, Randmaa I, Hahn RG. Hemodynamic effects of irrigating fluids studied
by Doppler ultrasonography in volunteers. Br J Urol 1996;77:541-6.
8. Lambert DH. Spinal Anesthesia. In: Rogers MC, Tinker JH, Covino BG,
Longnecker DE. Principles and practice of Anesthesiology. 1993, Mosby Year
Book, St. Louis, pp. 1275-6.
9. Lasater M. Managing inotrope therapy noninvasively. AACN Clin
Issues.1999;10:406-413.
10. Belott P. Bioimpedance in the pacemaker clinic. AACN Clin Issues. 1999;10:414-
418.
11. Nollert G, Reichart B. Registration of thoracic electrical bioimpedance for early
diagnosis of rejection after heart transplantation. Heart Lung Transplant.
1993:12:832-836.
12. Shoemaker WC, Wo CC, Bishop MH, Appel PL, Van der Water JM, Harrington
GR, Wang X, Patil RS. Multicenter trial of a new thoracic electrical bioimpedance
device for cardiac output estimation. Crit Care Med 1995;23:1785-6.
13. Scardo JA, Ellings J, Vermillion ST, Chauhan SP. Validation of bioimpedance
estimates of cardiac output in preeclampsia. Am J Obstet Gynecol 2000;183:911-3.
14. Velmahos GC, Wo CC, Demetriades D, Schoemaker WC. Early continuous
noninvasive hemodynamic monitoring after severe blunt trauma. Injury
1999;30:209-14.
15. Soderberg M, Hahn RG, Cederholm T. Bioelectric impedance analysis of acute
body water changes in congestive heart failure. Scand J Clin Lab Invest
2001;61:89-94.

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