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Changes in Intravesical Pressure During Irrigating Fluid Absorption in Transurethral Prostatic Surgery

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Summary. Continuous recording of intravesical pressure (IVP) and incremental volumetric measurements of irrigating fluid absorption were performed during 37 transurethral resections of the prostate (TUR). Absorption which resulted in concomitant dilutional changes in peripheral blood, indicating intravascular absorption, was associated with prolongation of the time required to increase the IVP. There was an inverse relation between the change in maximum IVP and the rate of irrigating fluid absorption. Absorption that did not result in concomitant dilutional changes in peripheral blood, indicating extravascular absorption, was associated with similar changes in IVP parameters but the critical pressure for absorption was lower.

Key words: Transurethral prostatectomy – Intravesical pressure – Irrigating fluid absorption – Fluid balance

Introduction

It has been established that the pressure in the prostatic fossa is of importance to the absorption of irrigant in transurethral prostatic surgery [5–11]. However, there have been different opinions about the relation between pressure and the degree of irrigant absorption. Several authors have suggested that absorption can be controlled by a reduction of the pressure in the prostatic fossa: Madsen and Naber [7] found a smaller absorption when the irrigating fluid bags were suspended 60 cm above the operating table instead of 70 and 90 cm and considered a pressure in the prostatic fossa of 4 kPa (30 mmHg) to be the critical level for massive absorption. Hultén et al. [5] suggested that the pressure in the prostatic veins, usually about 1.25 kPa (10 mmHg), has to be exceeded if absorption is to occur and they found massive absorptions at pressures at about 2 kPa (15 mmHg). Continuous drainage of the bladder has been advocated because a reduction of the pressure in the prostatic fossa can be achieved [6, 8, 10, 11]. Some clinical studies report less absorption with the continuous drainage technique when compared to the intermittend filling technique [8, 11] whilst other studies report no change [2, 9, 12].

The aim of this study was to find out if there is a pattern of pressure changes associated with massive absorption. The static intravesical pressure was measured since this determines the pressure in the prostatic fossa [4]. Irrigating fluid absorption was assessed by measuring the serum sodium changes and volumetric fluid balance in intervals of 10 minutes during TUR. When carried out carefully, the volumetric fluid balance shows a good correlation to the absorption as measured by radioisotopic methods [8].

Materials and Methods

Thirty-seven male patients underwent TUR for benign prostatic enlargement (mean age 70 years, range 56–82; mean weight of resected tissue was 4 g, range 8–60). All patients were given epidural anaesthesia. A Storz 27 Fr. resectoscope and the intermittent filling technique of the bladder were used. Intravenous infusions had a sodium content of 130 or 154 mmol · 1000 ml^{-1}. No erythrocyte transfusion or diuretic was given. The following measurements were made at 10 minute intervals (collection periods) during the resections:

Volumetric Fluid Balance, Blood Loss and Blood Samples

The irrigating fluid was 2.2% glycine in water. The bags were weighed to the nearest gram before and after use and suspended 60 cm above the estimated middle part of the patient's prostatic fossa. A sterile plastic drape that allowed no spillage on the floor was placed to facilitate collection of the irrigating fluid returns. A volumetric irrigating fluid balance was obtained every 10 min during the TUR by changing the irrigating fluid bag and collection bucket. The blood content of each collection bucket was measured, using the current blood haemoglobin concentration (B-Hb) for reference; the accuracy of the blood loss determination was 100 ± 6% as checked by dispersion of various amounts of bank blood in irrigating fluid. The volumetric fluid balance was corrected for blood loss to give the degree of absorption. Samples for determination B-Hb and serum sodium

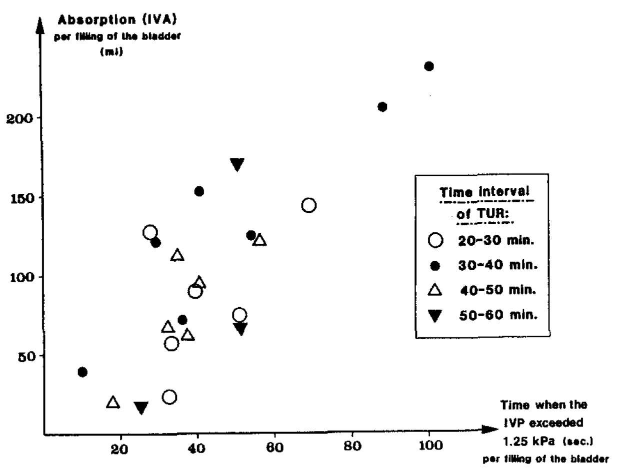

Fig. 1. The absorbed irrigant volume per filling of the bladder during collection periods with IVA occurring between 20 and 60 min of TUR versus the time when the IVP increase exceeded 1.25 kPa

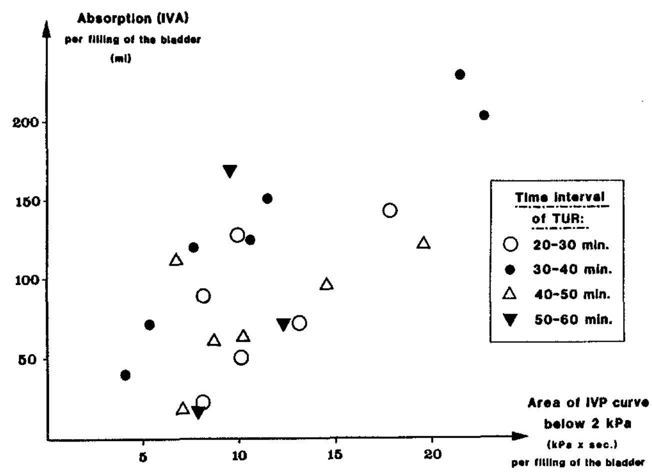

Fig. 2. The absorbed irrigant volume per filling of the bladder during collection periods with IVA between 20 and 60 min of TUR versus the area of the IVP curve below 2 kPa

concentrations (S-Na) were drawn through a cannula placed in the radial artery at the end of each collection period. B-Hb was analyzed on a Coulter Counter S plus and S-Na by flame photometry; coefficients of variation in serial analysis was 1.2% (B-Hb) and 0.55% (S-Na).

Criteria for Absorption

Volumetric fluid balances indicating retention of fluid were accepted as absorptions; if the volume of an absorption was < 100 ml · 10 min^{-1}, there was no accompanying significant change S-Na (2 mmol · l^{-1} or more; $P < 0.05$); when being greater than 100 ml · 10 min^{-1}, two different responses to absorption could readily be identified; absorption was either followed by:

a) a slow appearance of dilutional changes in circulating blood (*EVA*); there were neither a significant change in S-Na, nor an increase in CVP during the same time as the absorption occurred;

b) a rapid appearance of dilutional changes in circulating blood (*IVA*); there were a decrease in S-Na of 2 mmol/l or more ($P < 0.05$) and usually an increase in the CVP during the same time as the absorption occurred.

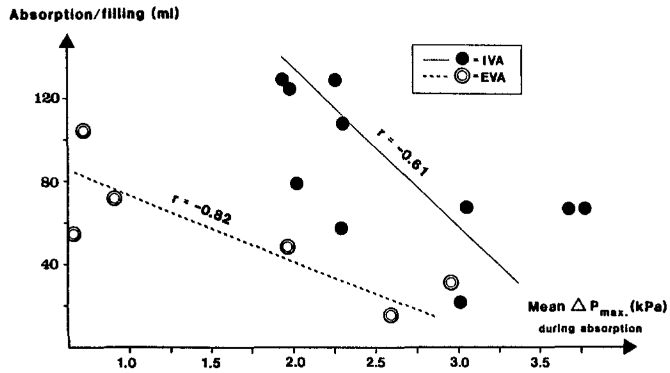

Fig. 3. The absorbed irrigant volume during EVA and IVA episodes versus the maximum intravesical pressure increase (ΔP_{max}). Mean values per intermittent filling of the bladder are considered

Intravesical Pressure (IVP) Variables and Central Venous Pressure (CVP)

A Cystofix^R suprapubic catheter was inserted into the bladder and a Drum-Cartridge^R central venous catheter placed with the tip in the superior vena cava before starting the TUR. The IVP and CVP were recorded continuously by a Hewlett-Packard 78342 A blood pressure monitor and printed by a Watanabe WTR miniwriter. The empty bladder when equilibrated with air through the open resectoscope and mid-heart level respectively were used as zero pressures. The results were not displayed to the surgeon during the TUR. The following intravesical pressure (IVP) variables were measured:

1) the number of bladder fills during each collection period;

2) the time that the increase of the pressure during each filling exceeded 1.25 respectively 2.0 kPa;

3) the maximum increase in the intravesical pressure (ΔP_{max}) for each bladder fill and

4) the product of pressure and time, i.e. the area below the intravesical pressure curve; the total area as well as the area when the pressure exceeded 2.0 kPa.

The study was approved by the Ethics Committee of Huddinge University Hospital. Mean values, standard deviation (SD), simple linear regression analysis, correlation coefficients, paired and unpaired *t*-tests were used for statistics. When a skewed distribution of data was obvious, means and unparied *t*-test were repaced by median values and Mann-Whitney's test. Correlations were considered significant when $P < 0.05$.

Results

The whole operative procedure was followed with IVP measurements and 10-minute volumetric balances in all patients; 32 IVA (median 357 ml, range 100–809), 15 EVA (median 325 ml, range 115–992) and 36 absorptions smaller than 100 ml were found during 176 monitored collection periods. The mean ± SD of the intravesical pressure increase (ΔP_{max}) for all fillings of the bladder (n = 748) was 2.48 ± 1.33 kPa (about 19 ± 10 mmHg).

The correlation coefficients for the absorbed irrigant volume versus the measured intravesical pressure (IVP) parameters in relation to fixed time intervals are shown in Table 1. The absorbed irrigant volume versus the time when the IVP exceeded 1.25 kPa during IVA episodes is

Table 1. Correlations between intravesical pressure parameters and the volume of irrigating fluid absorption (EVA and IVA) in time periods of 10 min during the first hour of 37 TURs. Three approaches were used; first by using the sum of values during each time period, second by considering the mean value per intermittent filling of the bladder, and third by excluding time periods without absorption from the analysis (the number of time periods included in the analysis is then shown in parenthesis)

Time of TUR (min)	Cases (n)	Area below curve		Area > 2 kPa		Time > 2 kPa		Time > 1.25 kPa		ΔP_{max}		Blood loss	
		EVA	IVA	EVA	IVA	EVA	IVA	EVA	IVA	EVA	IVA	EVA	IVA
0–10	37	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.54*** NS, NS
10–20	37	NS	NS	NS	NS	NS	NS NS −0.93**[5]	NS	NS	NS	NS NS −0.84*[5]	NS 0.50** 0.67*[10]	NS
20–30	37	NS	NS 0.44* NS	NS	NS	NS	0.60*** 0.58*** NS	ns	0.52*** 0.62*** NS	NS	NS	NS	0.53*** 0.37* NS
30–40	30	NS 0.43* NS	NS 0.77*** 0.85**[8]	NS	0.36* 0.48* NS	NS	0.56** 0.75*** 0.82**[8]	NS	0.68*** 0.81*** 0.87**[8]	NS	NS	0.62*** 0.94*** 0.99***	NS NS 0.77*
40–50	17	NS	0.57* 0.58* NS	NS	NS	NS	NS	NS	0.74*** 0.72** NS	NS	NS	NS	NS
50–60	9	NS	NS	NS	NS	NS	NS	NS	0.80* 0.77* NS	NS	NS	NS	NS

Correlation coefficients significant at * = $P < 0.05$, ** = $P < 0.01$ and *** = $P < 0.001$ are shown. If any of the three correlations is significant, all correlations are displaced

Table 2. A comparison between mean values of IVP parameters per intermittent filling of the bladder in 3 groups of patients; the first having no EVA/IVA (collection periods with absorption < 100 ml, if any, were excluded), second and third groups include the time periods of absorption in those who had EVAs or IVAs. Three patients having both EVAs and IVAs were excluded from the analysis. Mean values and SD are usually given and comparisons then made by unpaired *t*-test; when a skewed distribution of the patient mean values occurred, median and range are given and comparisons made by use of Mann-Whitney's test

Patient feature	*n*	Area below IVP curve (kPa · s)	Area > 2 kPa (kPa · s)	Time > 2 kPa (s)	Time > 1.25 kPa (s)	ΔP_{max} (kPa)	Number of fillings/ 10 min
No absorption	17	88.3 ± 42.2	8.4 (0–27.4)	8.9 (0–18.9)	19.3 ± 8.9	2.47 ± 0.91	4.6 ± 1.2
EVA	7	57.3 ± 39.4	1.7 (0–16.7)	7.3 (0–20.0)	17.9 ± 11.5	1.55 ± 0.95	5.0 ± 2.5
IVA	10	132.9 ± 50.5	17.7 (1.3–66.5)	20.5 (10.1–41.6)	39.7 ± 12.1	2.64 ± 0.71	4.5 ± 1.2
Selected statistics		No absorption vs. IVA; $P < 0.05$	No absorption vs. IVA; $P < 0.05$	No absorption vs. IVA; $P < 0.05$	No absorption vs. IVA; $P < 0.001$	No absorption vs. EVA; $P < 0.05$	No test performed

Table 3. IVP parameters during time periods of no absorption and time periods of IVA in 7 patients. The methods allow a comparison between these time periods. Values per filling of the bladder are consisdered. Paired *t*-test was used for statistics

Pat. no.	Time period	Area below IVP curve (kPa · s)	Area > 2 kPa (kPa · s)	Time > 2 kPa (s)	Time > 1.25 kPa (s)	ΔP_{max} (kPa)
1	IVA 21 ml/filling	107.8	18.9	21.4	36.0	3.02
	No absorption	83.0	9.7	12.0	22.4	2.12
2	IVA 79 ml/filling	85.3	1.3	10.8	20.1	2.01
	No absorption	43.1	1.9	2.9	6.9	1.83
3	IVA 108 ml/filling	78.0	6.0	12.8	34.2	2.35
	No absorption	66.9	9.0	12.2	19.8	2.67
4	IVA 65 ml/filling	86.2	26.2	20.3	26.5	3.67
	No absorption	66.1	9.2	10.2	15.5	2.84
5	IVA 65 ml/filling	164.0	40.5	35.0	53.5	3.81
	No absorption	119.0	26.7	23.0	31.8	3.39
6	IVA 124 ml/filling	143.1	16.4	10.3	41.5	1.91
	No absorption	88.2	14.0	12.5	13.6	3.34
7	IVA 124 ml/filling	159.0	26.4	41.6	57.7	2.27
	No absorption	104.6	16.6	18.5	26.6	2.37
1–7	Mean change IVA vs. no absorption	+ 44%	+ 55%	+ 70%	+ 98%	+ 5%
1–7	Significance level	$P < 0.01$	$P < 0.05$	$P < 0.05$	$P < 0.001$	NS

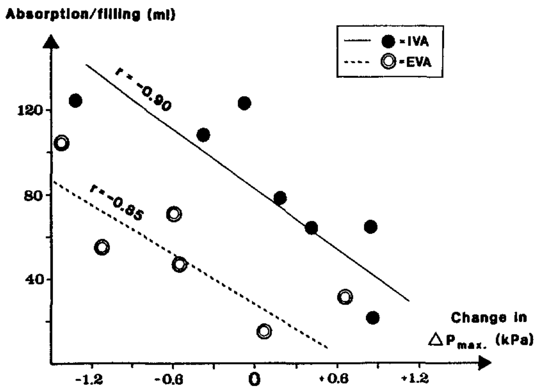

Fig. 4. The absorbed irrigant volume per intermittent filling of the bladder versus the difference in mean maximum IVP between time periods of no absorption and periods of absorption in the same patient. The largest absorptions correspond to a decrease of the mean maximum IVP

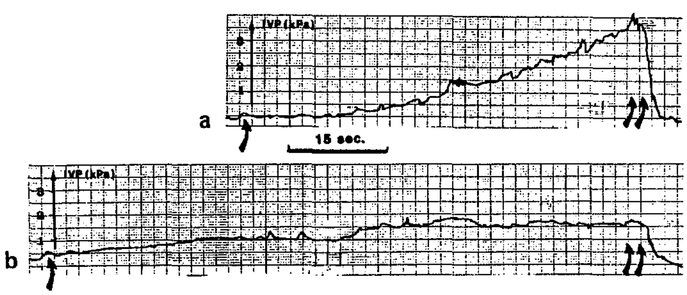

Fig. 5. a Intravesical pressure (IVP) curve from an intermittent filling of the bladder in a TUR when no absorption was recorded. **b** The IVP curve from the same patient as in **a**; during this printing, a massive IVA of 124 ml/filling of the bladder was recorded. The time lapse between the printings in **a** and **b** is 12 min. The beginning and end of each filling of the bladder are indicated by arrows

plotted in Fig. 1. When considering the area of the bladder pressure curve below 2.0 kPa and the time required for the pressure to increase from 1.25 kPa to 2.0 kPa (per filling of the bladder), there were significant correlations only to the volume of IVA for each 10-minute period between 20 and 50 minutes of TUR (r = 0.50–0.82) (Fig. 2).

Correlation factors for *each patient* were also calculated; these included the volume of IVA, EVA and the blood loss versus the value of each IVP parameter (per filling of the bladder) with consideration of time. There was no systematic correlation between these variables (median r = 0, range 0–0 for all variables and all patients).

The values for IVP variables during collection periods with absorption are displayed in Table 2. A lower mean ΔP_{max} indicated a larger absorption (Fig. 3). When absorption occurred during only a limited part of the operative procedure, the time period with absorption was compared to the time period of no absorption in the same TUR: during EVA ($n = 6$), ΔP_{max} was lower ($P < 0.05$; Fig. 4), and the time when the pressure exceeded 1.25 kPa was shorter ($P < 0.05$), than during time periods of no absorption; other changes in IVP variables were not significant. The results of a similar comparison in patients with IVA episodes ($n = 7$) are shown in Table 3 and Fig. 4. The typical changes of the IVP curve during a IVA is further illustrated in Fig. 5.

IVP variables were compared between patients with no absorption at all and time periods of no absorption in patients who experienced absorption during some other time period of the TUR. Patients with EVA had a tendency to have lower ΔP_{max} than those with no absorption, but this difference was not significant. Other variables showed quite similar values.

Discussion

Previous studies indicate that a certain critical pressure in the prostatic fossa has to be reached until an irrigant absorption can occur [5–7]. However, once the irrigant is absorbed at a rate suggesting that it is of importance to the fluid balance during TUR (> 100 ml · 10 min^{-1}), this study shows that greater absorption is not associated with a higher pressure (Fig. 3); when comparing the bladder pressure at times of no absorption to times of massive absorption in the same patient, pressures were lower during (Fig. 4; Table 3). These findings demonstrate a limited importance of ΔP_{max} measurementi to indicate the degree of irrigant absorption. Indeed, time variables are better related to absorption; there was an extension of the time required for increasing the bladder pressure in patients who showed large absorption (Tables 1–3; Figs. 1, 5). In such cases, the surgeon may extend the filling time because the visibility does not deteriorate. Similarly, when trying to inflate a punctured balloon, it takes a long time to fill but a high pressure is unlikely to be reached. In the case of an absorption during TUR, it takes a long time to fill the bladder although the ΔP_{max} will be only moderate or low, probably due to irrigating fluid leakage to the circulation.

The results support that the two kinds of absorption identified by the regular interval monitoring of patients correspond to different pathophysiological events (Tables 1–2; Figs. 3–4). A rapid decrease in S-Na (IVA) is the most likely to represent irrigant absorption through openen prostaic vessels because the medium then enters the circulation at a fast rate [7]; the immediate fluid loading of the circulation was further confirmed by monitoring the central venous pressure. A slow appearance of dilutional changes in circulating blood (EVA) probably corresponded to irrigating fluid extravasation and absorption to the perivesical space described by other authors [1, 3]. This kind of absorption can clearly occur at a lower pressure than IVA (Fig. 3); it seems like the irrigating fluid can move relatively freely between the bladder and perivesical space whenever an open perforation is created. There is a "punctured balloon" effect also during EVA (Fig. 4), although the reduction of the time that the IVP exceeded 1.25 kPa indicates a lower ciritical pressure for irrigating fluid to enter the perivesical space than to enter the circulating blood.

In this study, irrigating fluid absorption usually took place only during a limited time of the TUR. A comparison between times of no absorption in "absorbers" and "non-absorbers" showed negligible differences. Thus, no certain IVP pattern during a period of no absorption can indicate that an absorption will occur later in the TUR. This illustrates that the IVP profile has no predictive balue in identitying patients who will absorb irrigating fluid during TUR. The typical changes in IVP parameters seen during absorption should therefore be interpreted as reflections of the physiological events of IVA and EVA rather than risk factors for their occurrence.

Although the irrigating fluid bags were suspended at a height that would allow massive irrigating fluid absorptions due to Madsen and Naber [7], high pressures were generally not associated with absorption. The wide range of IVPs resulting from suspension the irrigating fluid bags at a certain height above the prostatic fossa suggests that other factors – possibly the operating technique of the surgeon and the elastic properties of the bladder – may be the major determinants of the pressure profile instead of the irrigating fluid bag height per se.

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