Understanding Renal Hydrodynamics

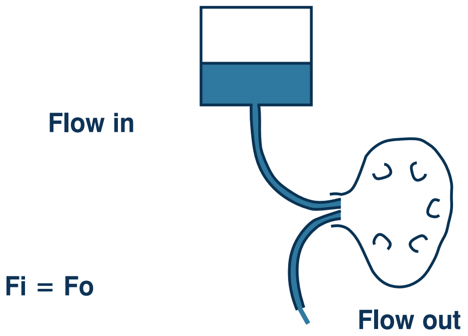
Irrigation is a mandatory requirement during any endoscopic procedure in the ureter or kidney. Irrigation is required for access into the ureter, and maintenance of visibility throughout the procedure, particularly during stone fragmentation to remove the vision obscuring dust. Good visibility should not come at the cost of a vastly increased intrarenal pressure and associated risk of pyelotubular and pyelovenous backflow, which in turn may lead to Systemic Inflammatory Response Syndrome (SIRS) or full-blown sepsis.

Helene Jung and Palle Osther [1] have shown that the baseline renal pelvis pressure is 10 (+/- 4.0) mm Hg. They showed that simple diagnostic ureterorenoscopy with forced flow continuous irrigation as low as 8ml/min will increase average renal pelvic pressure to 35 (+/- 10) mm Hg. During stone management, however, the average renal pelvic pressure can rise to 54 (+/-18) mm Hg. The same authors also showed that forced irrigation with a 20ml syringe is capable of producing peak pressures as high as 328 mmHg. This is very concerning, taking into account the threshold for pyelovenous backflow is reached at about 35 mmHg.

Wen Zhong studied the incidence of SIRS after flexible ureteroscopic lithotripsy [2] and found a strong statistical correlation ($p<0.001$) between the rate of SIRS and both total volume of fluid used for irrigation and flow rate.

Evidence suggests that we need to look for ways of reducing renal pelvic pressures during ureterorenoscopy, examining the role of forced continuous flow, overall flow rate, total volume of fluid used, maximal volume of bolus delivered, its timing, and the drainage capacity of the renal pelvis.

The main determinant of intrarenal pressure during ureterorenoscopy is the balance between inflow and outflow.



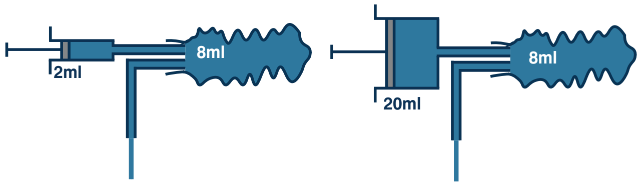
In order to prevent the build-up of dangerously high intrarenal pressures the inflow should match the outflow. Drainage of fluid from the renal pelvis is a limiting factor, even in the presence of UAS.

Pre-existing distention in the presence of limited outflow is dependent on the magnitude of continuous forced irrigation (inflow). Total volume of fluid used for irrigation is also an independent risk factor, as it is related to the same limiting factor of drainage from the renal pelvis.

The bolus size used in irrigation in comparison to renal pelvis capacity deserves careful consideration.

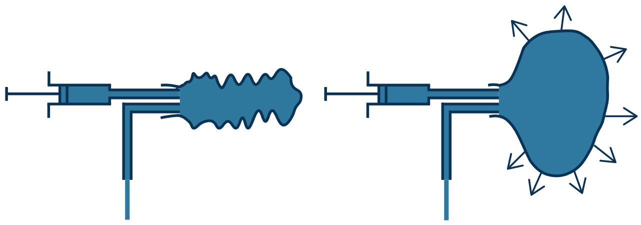
Delivering a bolus size many times larger than the total capacity of the renal pelvis (8-10ml) is bound to create a significant increase in pressure. This is important as most irrigation devices are capable of delivering a bolus with a volume lying between 150% and 300% of the total capacity of the renal pelvis.

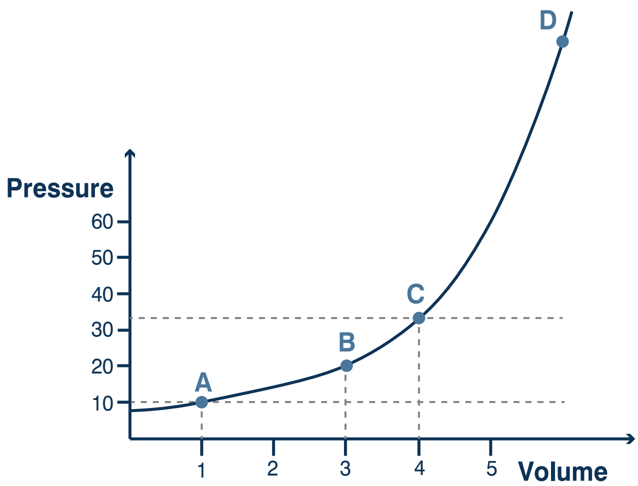
Bolus Size in relation to renal pelvis capacity



The human kidney is poorly compliant, and a small amount of liquid injected into it will result in a significant increase in pressure. The increase in the intrarenal pressure of a noncompliant body is exponential in nature. Initiating bolus delivery to a partially drained pelvis will initially cause little increase in renal pressure (A-B on pressure / volume curve), but when the renal pelvis becomes full even small volumes will result in a marked pressure increase (C-D on pressure / volume curve).

Effect of pre-existing intrarenal volume at the time of Bolus delivery





The most physiologically sound irrigation would call for elimination of forced continuous flow to keep the renal pelvis partially drained. The bolus would need to be much smaller than renal pelvis capacity. Such irrigation would move along the flat part of the compliance curve, thus preventing build up of excessive intrapelvic pressures.

Peditrol is a device consisting of a foot pedal and a single use, low volume pumping unit. It is capable of delivering dual flow, continuous gravity dependent flow that can be regulated by altering the height of the irrigation fluid, and accelerated flow in the form of a small bolus effected by the surgeon depressing the foot pedal. The maximal bolus size with single compression is limited to below 3ml; once the foot pedal is released the syringe refills automatically, and is ready for a further bolus if required. Recognition of the very low compliance of the human kidney, as well as the limitation of drainage from the kidney even in the presence of a ureteric access sheath, are key physiological foundations in understanding hydrodynamics during ureterorenoscopy and the basis of Peditrol design.

Peditrol offers limited bolus size, intermittent irrigation modality and provides clear views, allowing the surgeon to continue the procedure without the need to stop at regular intervals secondary to poor vision. The Peditrol can be used for hydrostatic distension that allows for easier introduction and advancement of the ureteroscope at the vesico-ureteric junction and the rest of the ureter. The pressure generated from the Peditrol is low, as the bolus delivered is limited to below 3mls. It frees up the surgeon's hands, allowing more precise control during the procedure, yet the control of irrigation is retained with the operator. It allows precise control of the irrigating fluid thus reducing stone retropulsion, particularly in ureteric stones. Peditrol provides intermittent irrigation, eliminating the need for forced flow, and as a result much more effective and adequate drainage of the renal pelvis is achieved between delivery of the low volume boluses. Lack of the continuous forced flow, together with limitation of the bolus size results in a significant reduction in total fluid used; up to 50% compared to forced irrigation devices [3].

Peditrol is safe and effective. In our institution it has been successfully used on hundreds of ureteroscopic procedures, both rigid and flexible, over the last 12 years. We do not use an access sheath routinely unless in a pre-stented patient with an infective stone. It represents the departure from continuous forced irrigation to a small intermittent bolus method, as a safer and more physiologically sound alternative.

References

1. Jung and Osther. SpringerPlus (2015) 4:373)
2. Journal of Endourology, "Systemic Inflammatory Response Syndrome after Flexible Ureteroscopic Lithotripsy , Study of Risk Factors" doi:10.1089/end2014.0409
3. Uropump versus Peditrol – a Prospective Comparative Study, K.Dattatray Wani. Mahesh Desai – poster presentation

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