The Whitaker Test

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Purpose: The Whitaker test was conceived and developed by Roger H. Whitaker (May 25, 1939) while he was a resident at Cambridge University in the late 1960s and early 1970s. The test combines a urodynamic study with antegrade pyelography to measure the pressure differential between the renal pelvis and the bladder. The test can differentiate between patients with residual or recurrent obstruction and those with dilatation secondary to permanent changes in the musculature.

Materials and Methods: We present the history of the Whitaker test and its place in modern practice.

Results: It is useful in evaluating patients with questionable ureteropelvic or ureterovesical junction obstruction and primary defects in the ureteral musculature. It can also be used to determine when percutaneous nephrostomy tubes can be safely discontinued in postoperative patients.

Conclusion: The merit of the Whitaker test in comparison to other less invasive tests, specifically diuretic renography, is the subject of much debate. However, such debate erroneously presupposes that the tests are directly comparable, which they are not. The correct use for the Whitaker test is to assesses potential upper tract obstruction in equivocal cases and should only be utilized when equivocal results are obtained by other less invasive tests, obstruction is suspected in a poorly functioning kidney, a negative renogram with colic, intermittent obstruction, and percutaneous access already exists and the cause of dilatation needs investigating.

Keywords: diagnostic techniques; urological; standards; dilatation; pathologic; diagnosis; pressure; ureteral obstruction; physiopathology.

INTRODUCTION

Dilatation and obstruction of the urinary tract are not synonymous and it is not possible to estimate the pressure in the renal pelvis by cross-sectional imaging. Even when an obstructing lesion, such as a ureteric calculus, is identified, the presence or absence of dilatation does not predict the extent to which ureter is obstructed. The correct diagnosis and treatment plan can often be determined by intravenous urography (IVU), ascending urogram, computed tomography (CT) scan with contrast and nuclear medicine isotope studies, such as diuretic renograms, when correlated with the symptom of pain as a surrogate for obstruction.

However, important additional information is occasionally required in the event that these noninvasive tests yield equivocal results. For instance, dilatation may result in a poorly emptying but not actually obstructed system, leading to the stagnation of urine flow and an increased risk of developing a urinary infection. Also, when dilatation is not resolved post-surgical repair, the question arises of whether the system is still obstructed. Additionally, a subgroup of patients with normal renograms consistently present with intermittent loin pain. In these situations, a Whitaker test can help differentiate cases of renal pathology from drug seeking or psychological pathology.

The increased use of cross-sectional imaging and early 'B' mode ultrasound in the 1950s and 1960s resulted in considerable advances in the understanding of abnormal ureters, especially in the pediatric population.[1] However, the measurement of renal pelvis pressure received little attention and there was no well-described way to distinguish between congenital or postoperative causes of obstruction and unobstructed dilatation. This all changed in 1972 when Roger H. Whitaker (Figure 1), a young resident from Cambridge University who had spent a year in the research lab at Johns Hopkins (1968-9), published the results of his studies and described his now eponymous test – the Whitaker Test.

While the concept of a dynamic perfusion-pressure flow (PPF) study was not new, with several animal model experiments and clinical trials already published,[1-3] all previous studies had used, at the least, a two cannula technique and did not describe an exact methodology based on sound physiologic principles.

MATERIALS AND METHODS

The Whitaker Test

Sustained complete obstruction of the ureter leads to complete loss of function and, as such, is easily diagnosed and must be treated by relieving the obstruction. In contrast, transient or partial obstruction offers a far more difficult clinical situation. While nephron loss will eventually occur, it is obviously preferable to identify and treat the obstruction prior to this irreversible confirmation. However, differentiating between transient or partial obstruction and dilatation is not possible with only a single pressure measurement in the renal pelvis or without knowledge regarding flow. Therefore, Whitaker developed a test to measure the pressure differential between the renal pelvis and the bladder at a steady flow based on several physical principles.

First, Bernoulli's principle states that under conditions of steady flow, the sum of all forms of mechanical energy in a fluid along a streamline is the same at all points in that streamline. Therefore, the velocity of a fluid is proportional to its dynamic pressure.

$$p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2) \qquad \rho$$

P = pressure; V= velocity; = density of water

However, application of this principle to the ureter is complicated as the diameter of the pipeline is not constant. Due to the Venturi effect, this causes differential speeds and pressures in the system (Figure 2). Moreover, the ureter is not a rigid tube and, as such, both intra-abdominal and intravesical pressure affect the upper tract. In fact, adjustment of the subject's position can result in a variation of 10-38 mm Hg in the renal pelvis.[4] Finally, the kidney continues to produce urine, resulting in a contribution to the flow from the nephrons that cannot be calculated. Whitaker overcame these issues by standardizing his methodology (Figure 3).

First, he pioneered the use of a single cannula, which he attached to a perfusion pump that maintained a fast flow rate of 10 mL per minute. The choice of 10 mL per minute was based in part on it being close to the physiologic maximum that a normal kidney can produce, meaning that the test is theoretically performed in a physiologic range. Also, by standardizing the flow rate the results could be compared among patients. Finally, the positioning of the patient was crucial for obtaining reproducible and interpretable results.

Early experiments were carried out on pigs at the Brady

Figure 1. Roger H. Whitaker, Cambridge University Staff photo.

Urological Institute at John Hopkins. Whitaker subsequently performed 170 studies on 112 patients with a history of equivocal obstruction based on previous conventional radiologic studies.[5] On the basis of these studies, he recognized five diagnostic patterns:

1. Unobstructed system: at a flow rate of 10 mL/min, absolute pressure (pressure within the renal pelvis once the pressure produced by perfusion of the nephrostomy tube or needle is subtracted) of less than 25 cmH2O and relative pressure (pressure drop across the site of suspected obstruction obtained by subtracting bladder pressure from absolute pressure) of less than 15 cmH2O.
2. Obstruction between the renal pelvis and bladder: relative pressure greater than 22 cmH2O and normal bladder pressure.
3. Hypertonic bladder: absolute pressure greater than 25 cmH2O with a partially filled bladder and relative pressure less than 15 cmH2O.
4. Hypertonic bladder and separate upper tract obstruction: both the absolute and relative pressures are elevated.
5. Equivocal or partially obstructed: relative pressure between 15 and 22 cmH2O.

Using his test, Whitaker was able to classify 96% of patients into groups 1-4. Only 4% of the cases remained equivocal.

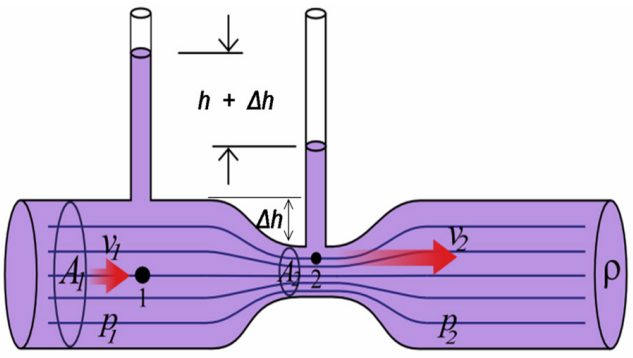

Figure 2. The pressure at "1" is higher than at "2" and the fluid speed at "1" is lower than at "2" because the cross-sectional area at "1" is greater than at "2".

RESULTS

Reception and Usefulness of the Test

While Whitaker's initial report generated significant interest, the exact place in the urologic armory for the Whitaker test has been widely debated over the last 40 years. Without question, prior to its inception there was a considerable gap in our understanding of upper tract dilatation and its relationship to transient or partial obstruction. Although it is not a physiological test, it is based on physiological principles. The standard infusion rate of 10 mL/min is an arbitrary number; however, the value was determined by Whitaker after extensive experimental and clinical observations.[6] Initially criticized as being too high, studies on healthy volunteers have shown that a kidney can produce 10 mL/min.[7] In fact, more recently the rate has been criticized as being too low, with rates of up to 20 mL/min being necessary to unmask transient, so-called high output, obstruction.[8] The clinical importance of these findings is limited, as these high rates, while possible, would seldom be seen. The exception would be in the case of Dietl's crisis, often seen in young men who drink large volumes of beer, when forced diuresis causes extreme pain due to an undiagnosed underlying ureteropelvic junction obstruction.

The Whitaker test is less accurate in massively dilated systems. Once the capacity of the renal pelvis exceeds 70 mL, its concordance with diuretic renography drops from nearly 90% to less than 50%.[9] In addition, some studies have found an inconsistent relationship between obstruc-

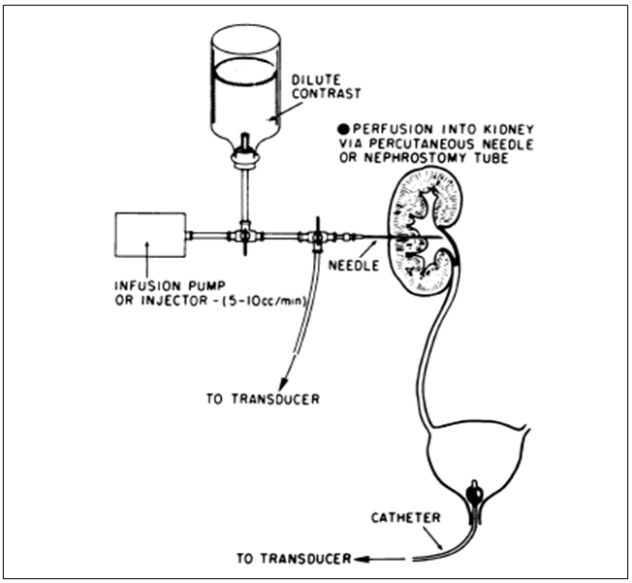

Figure 3. Whitaker test setup. Absolute pressure differences across the ureter are obtained by subtracting bladder pressure from renal pelvis pressure, which also cancels the effect of intra-abdominal pressure.

tion of the ureter and increased pressure in the renal pelvis. While the relationship should be consistent in an inelastic system, elastic recoil, which contributes to the pressure, can vary among patients with the same degree of obstruction. Some kidneys with almost completely obstructed ureters can maintain normal pressures.[10]

However, proponents of the test point out that low-pressure obstruction does not cause nephron damage. In fact, it is believed that a pressure above 22 cm H2O is required to cause damage,[11] and, as such, any clinically relevant obstruction, i.e. requiring treatment to prevent renal damage, can be identified by the Whitaker test. The Whitaker test is a dynamic test and interpretation of the numbers alone overlooks the purpose of the investigation in the first place, which is to make a diagnostic decision in the face of other equivocal tests.

CONCLUSION

Obstruction can only be defined in dynamic terms and the Whitaker test gives the most dynamic results. Therefore, it is not surprising that after 40 years it is still the go-to test in situations where other imaging and investigations have proved to be equivocal. The Whitaker test should not be the first choice of test, nor was ever designed to be used as such.[9] To quote Whitaker:

This type of pressure flow perfusion study must be kept in perspective. It is not a panacea for all obstructions and should not be used as a short cut to a quick diagnosis. That we have done only 170 such studies in 8 years for the many thousands of patients who have passed through our unit suggests that we have been selective and, indeed, many of our cases have been referred from other hospitals just for the study. However, the individual patient with such a difficult diagnostic problem should not be denied the advantage of a study since it may well be the only present means of obtaining the correct decision in terms of management'

We are indebted to Whitaker for his contribution to urology that has led to a greater understanding of dilated upper tract pathology. His test has helped many patients receive appropriate therapy that otherwise would have managed based on equivocal results.

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