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Histomorphological characteristics of the urinary bladder wall in human cadavers: An age-stratified analysis

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Abstract

Introduction: Histomorphological changes in the urinary bladder with age have a profound effect on bladder function and urologic health. The purpose of this investigation was to assess histomorphological features of the urinary bladder wall in various age groups to define normative parameters and recognize age-related structural changes.

Methods: A total of 70 human cadavers were allocated to three age groups: Group A (10–20 years, $n = 15$), Group B (21–40 years, $n = 36$), and Group C (41–65 years, $n = 19$). Weight of bladder, bladder capacity, interureteral distance, and histological parameters such as mucosal, muscular, and serosal thickness were measured. Statistical analysis was performed using *t*-tests to compare the parameters across the age groups.

Results: Group B had the highest mean bladder weight (98.36 g) and capacity (37.92 mL), followed by a decrease in older groups. The maximum interureteral distance was in Group B (2.78 cm). Serosal thickness was histologically significant between Group A and Groups B and C ($P = 0.007$ and $P = 0.010$, respectively). Trigonal muscular layer thickness was significantly different in all groups, with the greatest development in Group B and the greatest loss in Group C ($P < 0.001$).

Conclusion: Urinary bladder histomorphology is characterized by age-dependent patterns with optimal structure in middle adulthood (21–40 years) and cumulative changes with increasing age. The findings are helpful in supplying normative data on age-adjusted bladder function and establishing reference values for clinical application.

Keywords: Age-related changes, bladder function, bladder wall thickness, histomorphology, urinary bladder

Introduction

The urinary bladder is a highly plastic, complex, hollow viscus serving as a urine reservoir and storage organ, and for the controlled micturition by complex neuromuscular regulation.[1] Understanding histomorphological variation in the bladder wall across different age groups is critical to grasp functional alterations with aging and pathological processes involving this vital organ.[2] The wall of the bladder consists of several distinct layers, such as the urothelium, lamina propria, detrusor muscle, and serosa, each having different structural features that play a role in total bladder function.[3] Age-related changes in bladder structure and function have been extensively characterized, with significant implications for urological health and disease.[4] Previous studies have demonstrated that older age is associated with alterations in bladder compliance, capacity, and contractility, classically resulting in functional impairment and an increased susceptibility to pathologic conditions.[5,6] The detrusor muscle has certain changes with aging, with degeneration of muscle fibers, augmented collagen deposition, and altered innervation patterns.[7] Histomorphometric examination is greatly useful in elucidating the structural basis of age-dependent functional changes in the urinary bladder.[8] The thickness of various components of the bladder wall, including mucosa, musculature, and serosa, also varies noticeably among various ages, owing to the dynamic process of tissue remodeling during life.[9] Furthermore, regional variations within the bladder, particularly between the trigone and upper surfaces, have demarcated histological characteristics to be studied in detail.[10] The trigone region, located at the base of the bladder between the ureteral orifices and internal urethral meatus, possesses distinctive histological characteristics from those of the remaining bladder regions.[11] The area presents specialized muscular arrangements and diverse patterns of innervation that are accountable for its specific functional contribution to vesicoureteral reflux prevention and effective bladder emptying.[12] An awareness of these regional variations is critical in comprehending normal bladder physiology and disease alterations. Recent literature concentrates on the function of quantitative histomorphological analysis in establishing normative data for different age ranges and groups.[13] The aforementioned data serve as a foundation for identifying pathological changes and designing age-related treatment strategies for a range of urological pathologies. The present study aims to provide a thorough histomorphological description of the urinary bladder wall in different age ranges, supplementing the available body of knowledge and establishing reference parameters to be employed in follow-up clinical practice and research studies.[14]

Methods

This descriptive study was conducted in the Department of Anatomy, Sylhet MAG Osmani Medical College, in collaboration with the Department of Forensic Medicine, from January to December 2015. Seventy human urinary bladders were collected consecutively from unclaimed dead autopsied within 36 h of death, based on inclusion and exclusion criteria (excluding putrid bodies or those with gross bladder disease). The bodies were divided according to age: Group A (10–20 years), Group B (21–40 years), and Group C (41–65 years), and then further divided by sex. Urinary bladders were removed by routine autopsy technique, freed from overlying tissues, marked, and fixed in 10% formalin. Morphological measurements (weight, capacity, and distances between anatomical points) were made with routine instruments. Histological specimens (n = 18) were prepared using routine methods, stained with hematoxylin and eosin, and analyzed using the light microscope with an ocular micrometer to measure layer thickness. Records were made on a pre-tested data sheet and were analyzed in the Statistical Package for the Social Sciences, v21.0. Results are presented as mean ± standard deviation, with group comparisons done through unpaired t-tests. $P < 0.05$ was regarded as significant. Ethical clearance was taken from the ethical committee of the college before starting the study.

Results

Table 1 establishes that a majority of cadavers were Group B (21–40 years), which accounted for 51.4% of the total sample, then Group C (41–65 years) at 27.1%, and Group A (10–20 years) at 21.4%. This represents middle-aged individuals being best represented in the sample, and guarantees a representative sample for comparison purposes by age group.

Table 2 reveals that the study sample consisted of predominantly male cadavers (74.3%), with female cadavers at 25.7%. The sex ratio reflects a heavy preponderance of males, and this would have to be kept in mind during the interpretation of the differences in histomorphology, as sex-based anatomical variations could influence individual bladder characteristics.

Table 3 reveals that the average weight of the urinary bladder was highest in Group B (21–40 years) at 98.36 g, followed by Group C (41–65 years) at 86.16 g, and Group A (10–20 years) at 69.27 g. This trend demonstrates that bladder weight increases with age, being most profound during middle adulthood, and decreasing minimally with old age, possibly as an indicator of muscle mass changes or bladder elasticity with aging.

Table 4 also reveals that bladder capacity was highest in Group B (37.92 mL), Group C had a slightly lower mean capacity (33.32 mL), and Group A had the lowest capacity (31.20 mL). This pattern is as would be physiologically expected, because bladder capacity increases with age during growth and development, but decreases in older individuals due to the effects of aging on bladder compliance and muscle function.

Table 5 demonstrates that the distance between interureteral orifices was greatest in Group B (mean 2.78 cm), compared to Group C (2.44 cm) and Group A (2.30 cm). The increase in Group B may be associated with worldwide bladder growth and development during adulthood, while the slight decrease in Group C could be attributable to structural or functional alterations associated with aging.

Table 6 represents the histological measurements for different layers of the bladder. The mucosa of the surface was very variable in thickness (45.50–156.00 µm, mean 100.64 µm), whereas the musculature was extremely variable (156.25–512.50 µm, mean 314.46 µm). The serosal layer was relatively thin (mean 2.82 µm), but the trigone mucosa was extremely thin (mean 12.09 µm). The musculature of the trigone was most variable (206.25–719.00 µm, mean 387.81 µm), signifying structural differences across regions of the bladder.

Table 7 gives statistical differences in histomorphological parameters between age groups. The thickness of the mucosal layer of the superior surface was not significantly different in any of the groups. The serosal layer showed significant

Table 1: Distribution of cadavers by age group (*n*=70)

Age group	Number of cadavers	Percentage
Group A (10–20 years)	15	21.4
Group B (21–40 years)	36	51.4
Group C (41–65 years)	19	27.1

Table 2: Distribution of cadavers by sex (*n*=70)

Sex	Number of cadavers	Percentage
Male	52	74.3
Female	18	25.7

Table 3: Distribution of weight of urinary bladder by different age groups (*n*=70)

Age group (number of specimens)	Mean weight (g)	Standard deviation	Range (g)
Group A (*n*=15) 10–20 years	69.27	±31.78	23.0–111.0
Group B (*n*=36) 21–40 years	98.36	±21.80	65.0–130.0
Group C (*n*=19) 41–65 years	86.16	±16.98	66.0–115.0

Table 4: Distribution of capacity of urinary bladder by different age groups (*n*=70)

Age group (number of specimens)	Mean capacity (mL)	Standard deviation	Range (mL)
Group A (*n*=15) 10–20 years	31.20	±7.28	16.0–40.0
Group B (*n*=36) 21–40 years	37.92	±7.31	25.0–50.0
Group C (*n*=19) 41–65 years	33.32	±6.13	25.0–46.0

Table 5: Distance between two ureteral orifices by different age groups (*n*=70)

Age group (number of specimens)	Mean distance (cm)	Standard deviation	Range (cm)
Group A (*n*=15) 10–20 years	2.30	±0.55	1.5–3.3
Group B (*n*=36) 21–40 years	2.78	±0.32	2.3–3.5
Group C (*n*=19) 41–65 years	2.44	±0.42	2.2–3.5

differences: Group B and Group C both had much thicker serosal layers than Group A (P = 0.007 and P = 0.010, respectively), with no difference found between B and C. The muscular layer of the trigone showed very high differences between Group A and B ($P < 0.001$) and Group B and C ($P < 0.001$), indicating greater musculature in Group B. These findings suggest that most developed histomorphological growth is present in middle-aged individuals in certain structures of the bladder wall.

Discussion

The present study brings forth significant age discrepancies in histomorphological parameters of the urinary bladder wall, whose findings confirm and supplement current evidence in this field. Our findings indicate maximum bladder weight and volume in the 21–40 years age group, consistent with studies, indicating corresponding patterns of bladder growth and maturation during early to mid-adulthood.[15,16] The average bladder weight of 98.36 g observed in this group falls within the range reported in healthy adult populations.[17] Similarly, our maximum capacity measurements of maximal capacities of 37.92 mL in the same age group are comparable to morphometric measurements, which reported increases in functional bladder capacities with advancing early adulthood, followed by a stepwise reduction with advancing age.[18,19] Our study's measurements of inter-ureteral distances (2.78 cm in Group B) are consistent with anatomical reports, which reported analogous dimensional alterations related to bladder growth and development.[4,20] Our findings of progressive diminution in distances with increasing age contrast with some reports, suggesting the presence of possibly population-related variations in bladder morphometrics.[21] Histological analysis revealed significant differences in serosal thickness among the age groups, with Groups B and C each having significantly thicker layers compared to Group A (P = 0.007 and P = 0.010, respectively), which is in agreement with previous reports showing progressive structural changes in the bladder wall with advancing age.[22,23] The absence of significant differences in mucosal thickness with age supports earlier observations indicating

Table 6: Histological parameters of urinary bladder (n=18)

Parameter	Range (μm)	Mean (μm)	Standard deviation (μm)
Thickness of mucosa (superior surface)	45.50–156.00	100.64	±30.99
Thickness of musculature (superior surface)	156.25–512.50	314.46	±111.66
Thickness of serosa (superior surface)	1.25–4.50	2.82	±0.90
Thickness of mucosa (trigone)	6.25–25.00	12.09	±5.15
Thickness of musculature (trigone)	206.25–719.00	387.81	±137.85

Table 7: Comparison of histomorphological parameters of the urinary bladder wall by age group (t-test analysis)

Parameter	Comparison	t-value	P-value	Significance
Thickness of the mucosal layer of the superior surface	Group A versus B	−1.825	0.098	Not significant
	Group A versus C	−1.404	0.191	Not significant
	Group B versus C	0.218	0.832	Not significant
Thickness of the serosal layer of the superior surface	Group A versus B	−3.379	0.007	Highly significant
	Group A versus C	−3.195	0.010	Significant
	Group B versus C	−1.145	0.279	Not significant
Thickness of the muscular layer of the trigone	Group A versus B	−6.456	<0.001	Highly significant
	Group A versus C	−1.197	0.259	Not significant
	Group B versus C	6.954	<0.001	Highly significant

relative stability of the urothelial layer throughout life.[24,25] The trigonal muscular layer demonstrated highly significant age-dependent differences, with the greatest development in middle adulthood and marked reduction in older age ($P < 0.001$ for comparisons between Groups A and B, and Groups B and C). This supports previous findings that identified regional variations in bladder muscle development and the theory of age-related functional decline.[13,26,27] It is important to consider that the sample in this study had a male predominance (74.3%), which may influence the generalizability of the findings. However, this is consistent with trends reported in cadaveric studies.[28] Subsequent studies should aim at having a more balanced sex distribution to clarify gender-related differences in bladder histomorphology.

Limitations of the study

The study was also limited by a predominantly male sample (74.3%), possibly affecting the generalizability of the findings to female populations. The relatively low sample size in each group, particularly Group A ($n = 15$), may limit statistical power to detect small differences. Furthermore, the cadaveric nature of the study may not accurately mimic *in vivo* bladder properties due to post-mortem changes and fixation artifacts.

Conclusion

This study demonstrates significant age-related changes in urinary bladder histomorphology, with the highest structural parameters in the age group of 21–40 years. The findings reveal typical patterns of bladder wall growth and involution, best seen in serosal and trigonal muscular layers. These data offer important normative information for different age groups and bring to light the structural mechanisms of age-dependent bladder dysfunction. The precise morphometric study assists in uncovering normal bladder aging processes and may offer clinical decision-making clues for urological treatment. More extensive sets of samples with the same sex ratio should be included in future research to validate these data.

Recommendation

Based on the findings of this study, it is recommended that future research should include larger and more balanced samples with equal representation of both sexes to better assess potential gender-related differences in urinary bladder histomorphology. In addition, *in vivo* studies using imaging or functional assessments are suggested to complement cadaveric data and minimize the influence of post-mortem changes. Establishing comprehensive, age-specific normative bladder parameters can aid clinicians in diagnosing and managing age-related bladder dysfunctions more accurately. These findings should also encourage the development of age-adjusted urological treatment guidelines that consider the structural variations of the bladder wall across the lifespan.

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Conflict of Interest

None declared.

Ethical Approval

The study was approved by the Institutional Ethics Committee.

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