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Trends Over 20 Years of Antimicrobial Prophylaxis for Artificial Urinary Sphincter Surgery

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Trends over 20 years of antimicrobial prophylaxis for artificial urinary sphincter surgery

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Abstract

Introduction and Objective: Perioperative antimicrobial prophylaxis is crucial for prevention of prosthesis and patient morbidity after artificial urinary sphincter (AUS) placement. While antibiotic guidelines exist for many urologic procedures, adoption patterns for AUS surgery are unclear. We aimed to assess trends in antibiotic prophylaxis for AUS and outcomes relative to American Urological Association (AUA) Best Practice guidelines.

Methods: The Premier Healthcare Database was queried from 2000 to 2020. Encounters involving AUS insertion, revision/removal, and associated complications were identified via ICD and CPT codes. Premier charge codes were used to identify antibiotics used during the insertion encounter. AUS-related complication events were found using patient hospital identifiers. Univariable analysis between hospital/patient characteristics and use of guideline-adherent antibiotics was done via chi-squared and Kruskal–Wallis tests. A multivariable logistic mixed effects model was used to assess factors related to the odds of complication, specifically the use of guideline-adherent versus nonadherent regimens.

Results: Of 9775 patients with primary AUS surgery, 4310 (44.1%) received guideline-adherent antibiotics. The odds of guideline-adherent regimen use increased 7.7% per year with 53.0% (830/1565) receiving guideline-adherent antibiotics by the end of the study period. Patients with guideline-adherent regimens had a decreased risk of any complication (odds ratio [OR]: 0.83, 95% confidence interval [CI]: 0.74–0.93) and surgical revision (OR: 0.85, 95% CI: 0.74–0.96) within 3 months; however, no significant difference in infection within was noted (OR: 0.89, 95% CI: 0.68–1.17) within 3 months.

Conclusions: Adherence to AUA antimicrobial guidelines for AUS surgery appears to have increased over the last two decades. While guideline-adherent regimens were associated with decreased risk of any complication and surgical intervention, no significant association was found with risk of infection. Surgeons appear to be increasingly following AUA recommendations for antimicrobial prophylaxis for AUS surgery, however, further level 1 evidence should be obtained to demonstrate conclusive benefit of these regimens.

KEYWORDS
antibiotics, artificial urinary sphincter, guidelines, prophylaxis

1 | INTRODUCTION

Male stress urinary incontinence (SUI) is a form of urinary incontinence characterized by involuntary urine loss upon physical exertion or effort and has a notable impact on quality of life.[1] SUI often occurs as a byproduct of prostate cancer or benign prostatic hyperplasia treatment, as well as from trauma, iatrogenic injury, or neurologic dysfunction. Like other forms of incontinence, SUI prevalence increases with age, with estimates rising from <1% in men under 44 years to nearly 5% in men over 65.[2]

The artificial urinary sphincter (AUS) is the most effective treatment for SUI and is considered the gold standard therapy with recommended use even for severe SUI after radiotherapy for prostate cancer.[1] However, despite the efficacy of AUS, 10%–40% of patients with an AUS require surgical revision after initial placement; 1%–11% of these are attributed to infection.[3–5] Infection is a particularly troublesome complication for prostheses, as these patients are even more likely to require repeat procedures if reimplantation is pursued.[6–8]

The American Urological Association (AUA) first provided guidance on perioperative infection prevention in their 2008 Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis, with an update in 2012 to include aztreonam as an alternative to aminoglycosides for patients with renal insufficiency.[9] These guidelines are consistent in the 2019 update.[10] There is controversy regarding these recommendations, as no high-quality studies exist for either AUS or penile prostheses demonstrating a clear benefit in infection risk with these preferred regimens.[11,12]

Given the low quality of evidence but widespread reach of the AUA guidelines, is unclear how the guideline has influenced antimicrobial preference in the urologist's practice. We aimed to assess changes in antibiotic preferences before and following publication of AUA Best Practice guidelines and whether adherence to the recommendations was associated with a difference in acute AUS complications. We hypothesized that the publication of the AUA Best Practice guidelines would be associated with increased usage of the AUA-recommended antibiotic regimens and decrease in overall postoperative complications.

2 | METHODS

2.1 | Study population

The Premier Healthcare Database (PHD) was queried to identify all encounters from the first quarter (Q1) of 2000 to Q1 of 2020 with a Current Procedural Terminology (CPT) or International Classification of Diseases (ICD)-9/10 procedural code for male patients with AUS insertion, revision/removal, and associated complications (Supporting Information: Table S1). The PHD is a national hospital-based encounters data set that captures approximately 20% of United States hospital discharges which has been well-described previously.[13,14] For patients with multiple encounters for AUS insertion, only the first chronological encounter was selected. The cohort was divided into 3-year intervals over the study period. Premier charge codes were used to identify antibiotics administered during the insertion encounter. Antibiotics were grouped into categories based on antibiotic classification. The day on which a particular item was billed was used to identify whether administration was "guidelines-based" (Day 0 or 1) or not (Day ≥ 2 or after).

2.2 | Outcomes

The primary outcome was adherence to previously published AUA Best Practice guidelines, defined as (1) aminoglycoside + first/second generation cephalosporin, (2) aminoglycoside + vancomycin, (3) monobactam (aztreonam) + first/second generation cephalosporin, (4) monobactam + vancomycin, or (5) aminopenicillin + beta-lactamase inhibitor. Antibiotic regimens were considered nonadherent if antibiotics were given beyond postoperative Day 1, nonguideline adherent antibiotics were used, or additional antibiotics in addition to guideline-adherent regimens were used. Additional subanalyses were performed to assess use of antifungals or other antimicrobials in addition to a guideline-based regimen to account for local antibiograms and/or preoperative culture-directed prophylaxis. Complications associated with AUS were identified during index and on subsequent encounters and linked via the patients' unique within-hospital identifier. "Complication" included infectious complications, device failure, and diagnoses captured under "other complications of genitourinary prosthetic devices" in ICD-10 or "other mechanical complication of genitourinary device" in ICD-9. A secondary outcome assessed specific complications within 3 months including surgical revision/removal, device/wound infection, and emergency department (ED)/inpatient readmission. A sensitivity analysis of only outpatient surgery patients (length of stay < 1 day) was performed given that it was not possible to determine the reasons for postoperative admission such as reverse causation (e.g., unplanned inpatient admission causing extension of antibiotics beyond 24 h). Due to database limitations, only encounters occurring at the same hospital as the index surgery were captured. Postdischarge antibiotic usage was also not available, as prescription data is not available in PHD.

2.3 | Statistical analysis

Univariable analysis of the association between hospital/patient characteristics and use of guideline-based antibiotics was done via Chi-squared and Kruskal–Wallis tests. Univariable analysis was also done to assess hospital/patient characteristics between patients that had a revision/removal event within 3 months and those that did not. Multivariable logistic mixed effects models were used to determine the odds of guideline-based antimicrobial use over the study period, as well as any complication and revision/removal events. The mixed effects models for complication and revision rates included patient age (by decade), race, diabetes (with or without chronic complications), concurrent insertion of a penile prosthesis, whether the encounter was inpatient or outpatient, region, hospital size, and academic affiliation/teaching status as covariates with our primary interest in the odds ratio (OR) for AUA-adherent regimens versus those with nonadherent regimens. History of radiation was initially evaluated, however, due to the lack of billing codes specifically for pelvic radiation, this was not included in the final model. The models also included a hospital-specific random effect to account for clustering of encounters within hospitals. All analysis was done using R (version 4.1.2) with the lme4 package.[15]

3 | RESULTS

3.1 | Cohort demographics

A total of 10 032 patients had an index AUS surgery between 2000 and 2020. We excluded 257 patients that were not male, missing age data or under 18 years old from further analysis. Of the remaining 9775 patients (Table 1), the mean age was 69.9 years with the majority identifying as Caucasian (7314/9775, 74.8%) and utilizing Medicare (7030, 71.8%). The number of AUS insertions increased from 654 in 2000–2002 to 1565 in 2018–2020. Most insertions were performed between 2012 and 2014 (2220, 22.7%) compared to other time intervals, at nonteaching hospitals compared to teaching hospitals (5257, 53.8%) and in the South compared to other regions (5266, 53.9%).

3.2 | Guideline adherence

Guideline-adherent antibiotics were used in 4310/9775 (44.1%) patients (Table 1). Patients with guideline-adherent antibiotics were more likely to have had their index surgery later in the study period ($p < 0.001$), have a race of White ($p < 0.001$), and have commercial insurance ($p = 0.03$). Guideline-adherent patients also had a lower average LOS (0.2 vs. 0.6, $p < 0.001$) and were more likely to have had AUS insertion at facilities in the South or West ($p < 0.001$) that had >400 beds ($p < 0.001$). Guideline-adherent patients were more likely to have a history of radiation therapy ($p = 0.01$). Both guideline-adherent and nonadherent groups were similar in age, history of diabetes, concurrent penile prosthesis insertion, and academic affiliation. The most frequently used AUA-adherent regimen was gentamicin + vancomycin. The most commonly used antibiotic regimens overall were gentamicin + vancomycin, cefazolin + gentamicin, and cefazolin + gentamicin + vancomycin.

The proportion of guideline-adherent antibiotic usage increased from 32.6% (212/654) in 2000–2002 to 53.0% (830/1565) of encounters in 2018–2020 (Figure 1). From initial best practice publication to the end of the study period, there were sharp increases in the use of aminoglycoside + vancomycin and decreases in aminoglycoside + first generation cephalosporin (Figure 2A). When antibiotics were assessed individually, only first generation cephalosporins, aminoglycosides, glycopeptides, and quinolones were used in over 10% of all encounters. Of these, there was an increase in the use of aminoglycosides and vancomycin over the study period, while first generation cephalosporin and fluoroquinolone use decreased

TABLE 1 Characteristics at insertion encounter of index artificial urinary sphincter (AUS) implant encounters between 2000 and 2020.

Characteristic	All patients	Guideline-adherent	Nonguideline adherent	*p*-value
N (%)	9775 (100%)	4310 (100%)	5465 (100%)	
Age in years, mean (SD)	69.9 (9.1)	70.0 (8.8)	69.9 (9.3)	0.78
Race				**<0.001**
White	7314 (74.8%)	3301 (76.6%)	4013 (73.4%)	
Black	929 (9.5%)	389 (9.0%)	540 (9.9%)	
Hispanic	404 (4.1%)	195 (4.5%)	209 (3.8%)	
Other/Unknown	1128 (11.5%)	425 (9.9%)	703 (12.9%)	
Charlson Comorbidity Index, mean (SD)	1.2 (1.6)	1.2 (1.6)	1.2 (1.6)	0.47
History of diabetes	2052 (21.0%)	885 (20.5%)	1167 (21.4%)	0.12
Concurrent penile prosthesis insertion	642 (6.6%)	290 (6.7%)	352 (6.4%)	0.6
History of radiation	1178 (12.1%)	562 (13.0%)	616 (11.3%)	**0.01**
LOS in days, mean (SD)	0.4 (1.4)	0.2 (0.6)	0.6 (1.8)	**<0.001**
Insurance type				**0.03**
Commercial	426 (4.4%)	207 (4.8%)	219 (4.0%)	
Managed care	1810 (18.6%)	790 (18.3%)	1020 (18.6%)	
Medicaid	185 (1.9%)	72 (1.7%)	113 (2.1%)	
Medicare	7030 (71.8%)	3121 (72.4%)	3909 (71.5%)	
Selfpay	32 (0.3%)	12 (0.3%)	20 (0.4%)	
Other	292 (3.0%)	108 (2.5%)	184 (3.4%)	
Region				**<0.001**
Midwest	1469 (15.0%)	583 (13.5%)	886 (16.2%)	
Northeast	1395 (14.2%)	578 (13.4%)	817 (15.0%)	
South	5266 (53.9%)	2360 (54.7%)	2906 (53.2%)	
West	1645 (16.8%)	789 (18.3%)	856 (15.7%)	
Teaching hospital				0.72
No	5257 (53.8%)	2307 (53.6%)	2950 (53.9%)	
Yes	4518 (46.2%)	2003 (46.4%)	2515 (46.1%)	
Hospital beds				**<0.001**
0–99	122 (1.2%)	32 (0.7%)	90 (1.6%)	
100–199	1214 (12.4%)	572 (13.3%)	642 (11.7%)	
200–299	1195 (12.2%)	392 (9.1%)	803 (14.7%)	
300–399	1372 (14.0%)	622 (14.4%)	750 (13.7%)	
400–499	1951 (20.0%)	971 (22.5%)	980 (17.9%)	
500+	3921 (40.1%)	1721 (39.9%)	2200 (40.3%)	

Note: Bold values are significant $p < 0.05$.

(Figure 2B). Only 5% of patients received antibiotic therapy beyond 24 h. The logistic mixed effects model showed a 7.7% increase in odds of guideline-based antimicrobial use per year (Figure 3).

A subanalysis of regimens which included any guideline-adherent antibiotics with the addition of other antimicrobials revealed few instances of guideline + antifungal use (74/9775, 0.8%), while a quarter of patients received guideline +

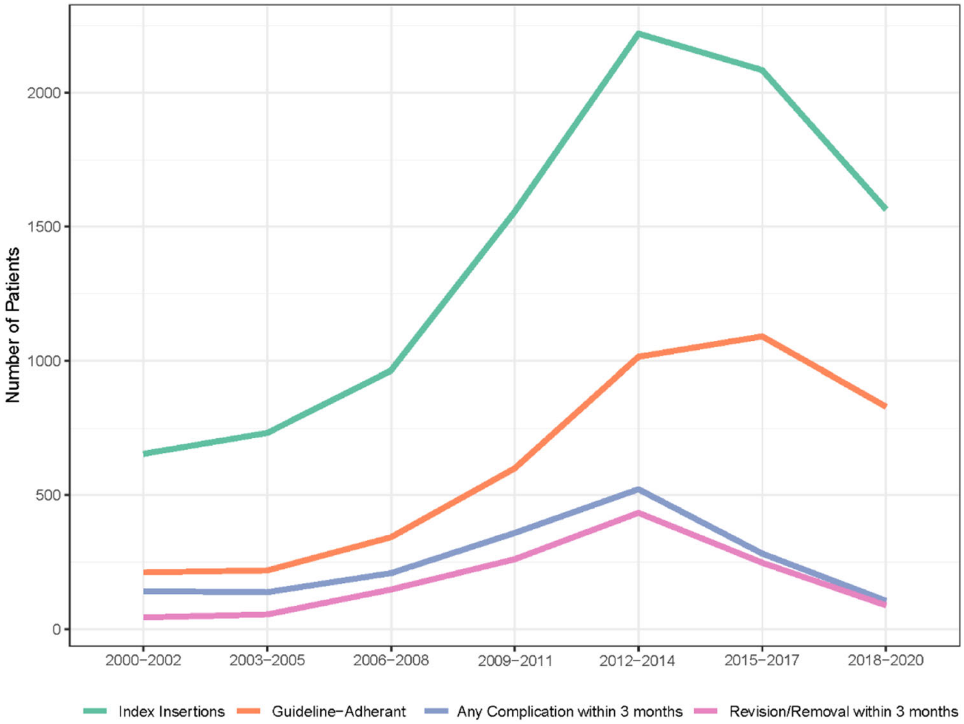

FIGURE 1 Number of artificial urinary sphincter (AUS) patient encounters within the Premier Health Database (PHD) from quarter 1 (Q1) of 2000 to Q1 of 2020. Note the number of hospitals contributing data to the PHD varies over time.

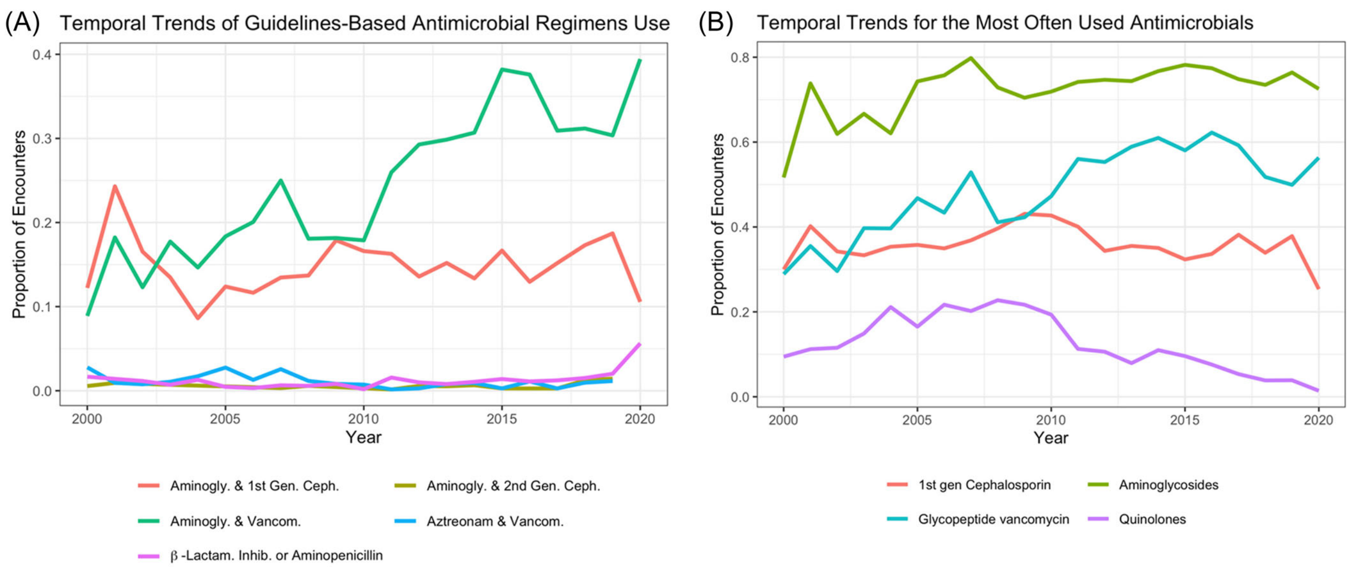

FIGURE 2 (A) Prevalence of guideline-adherent antibiotic regimen use over the study period. (B) Individual antibiotic usage trends of antimicrobials used in ≥10% of encounters.

any other antimicrobial (2338, 23,9%). The guideline + antifungal group had a higher incidence of diabetes ($p = 0.02$) and concurrent penile prosthesis insertion ($p < 0.001$) compared to other groups. A mixed effects model of likelihood for complications can be found in Supporting Information: Table S3, however, these results should be viewed with caution as the instances are too low to be conclusive.

3.3 | Device complications

The 3-month complication rate was 18.0%, with 246/1758 (14.0%) due to infection. There were 21 (1.2%) instances of bleeding and 111 (6.3%) of urinary retention. We found a lower rate of complications (16.2% vs. 19.4%, $p < 0.001$) in the guideline-adherent group compared to the nonguideline adherent group, including a lower infection

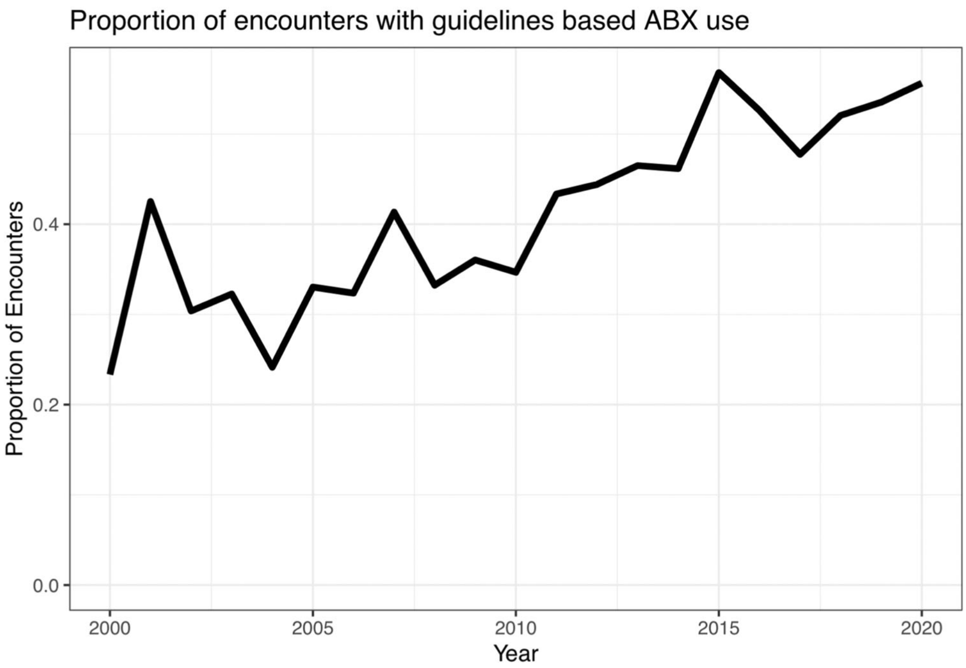

FIGURE 3 Proportion of artificial urinary sphincter (AUS) encounters utilizing guideline-adherent antimicrobial use over the study period. The odds of guideline-adherent regimens increased by an average of 7.7% per year.

rate (6.1% vs. 7.2%, $p = 0.029$). However, there was no significant difference in 3-month revision/removal events (12.4% vs. 13.7%, $p = 0.066$) or ED/inpatient readmission (11.2% vs. 11.8%, $p = 0.38$). There were few instances of device failure within 3 months (Supporting Information: Table S2).

In the mixed effects model, patients receiving guideline-adherent antibiotic regimens had a 0.83 OR (95% confidence interval [CI]: 0.74–0.93) of any subsequent complication within 3 months compared to nonadherent regimens (Table 2). The combinations of aminoglycoside + first generation cephalosporin and aminoglycoside + vancomycin specifically demonstrated a statistically significant reduction in complications within 3 months ($p = 0.03$ and $p = 0.017$, respectively). Each decade increase in age was associated with a 28% increase in any complication (95% CI: 1.20–1.36). Postoperative admission was also associated with increased risk of any complication (OR: 1.30, 95% CI: 1.14–1.48). On sensitivity analysis of outpatient procedures only, increasing age was the only significant predictor of any complication (OR: 1.34, 95% CI: 1.24–1.44). No significant change in complications was noted with race, diabetes, concurrent penile prosthesis insertion, region, or hospital size/teaching affiliation.

A mixed effects model for infectious complications within 3 months demonstrated no significant difference in risk between guideline-adherent versus nonadherent regimens (OR: 0.89, 95% CI: 0.68–1.17). Infection risk was associated with increased age (OR: 1.34, 95% CI: 1.15–1.57), diabetes (OR: 1.65, 95% CI: 1.25–2.19), and postoperative admission (OR: 2.33, 95% CI: 1.76–3.10). Similarly, there was no significant difference in risk in 3-month ED/inpatient readmission between guideline versus nonadherent regimens (OR: 0.98, 95% CI: 0.86–1.12). Increasing age (OR: 1.13, 95% CI: 1.05–1.21), diabetes (OR: 1.52, 95% CI: 1.31–1.75), and postoperative admission (OR: 1.27, 95% CI: 1.09–1.48) were associated with higher risk of ED/inpatient readmission. On sensitivity analysis, increasing age (OR: 1.19, 95% CI: 1.09–1.30) and diabetes (OR: 1.37, 95% CI: 1.15–1.63) persisted as significant predictors of readmission.

The overall revision/removal rate over the study period was 14.1% (1380/9775). There was no statistical difference in device revision/removal within 3 months (12.4% vs. 13.7%, $p = 0.07$) (Table 1 and Supporting Information: Table 2). The mixed effects model showed a lower risk of surgical revision/removal within 3 months (OR: 0.85, 95% CI: 0.74–0.96) with any guideline-adherent antibiotic use. There was a significantly higher probability of revision/removal with older age (OR: 1.3, 95% CI: 1.21–1.40), but a lower probability for patients admitted postoperatively (OR: 0.55, 95% CI: 0.46–0.65). On sensitivity analysis, only increasing age persisted as a significant predictor of revision/removal. No significant difference was seen in device revision/removal with race, diabetes, concurrent penile prosthesis insertion, region, or hospital size/teaching affiliation.

TABLE 2 Odds ratio (OR) of artificial urinary sphincter (AUS) complication events within 3 months using a logistic mixed effects model of patient and hospital characteristics.

	Any complication			Infection			Revision/removal		
Characteristic	**OR**	**95% confidence interval [CI]**	***p*-value**	**OR**	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**
Age (by decade)	1.28	1.20–1.36	**<0.001**	1.34	1.15–1.57	<0.001	1.30	1.21–1.40	**<0.001**
Race									
White	Ref			Ref			Ref		
Black	0.91	0.74–1.11	0.3	0.78	0.47–1.30	0.3	0.89	0.71–1.12	0.3
Hispanic	0.98	0.74–1.31	>0.9	0.99	0.49–2.00	>0.9	0.97	0.70–1.35	0.8
Other/Unknown	1.04	0.87–1.24	0.7	1.10	0.73–1.64	0.7	1	0.81–1.24	>0.9
History of diabetes									
No	Ref			Ref			Ref		
Yes	1.04	0.92–1.19	0.5	1.65	1.25–2.19	**<0.001**[a]	1.03	0.89–1.20	0.7
Postoperative admission									
No	Ref			Ref			Ref		
Yes	1.30	1.14–1.48	**<0.001**	2.33	1.76–3.10	**<0.001**	0.55	0.46–0.65	**<0.001**
Concurrent penile prosthesis insertion									
No	Ref			Ref			Ref		
Yes	0.86	0.68–1.08	0.2	1.30	0.80–2.10	0.3	0.77	0.59–1.02	0.069
Region									
Midwest	Ref			Ref			Ref		
Northeast	1.06	0.81–1.40	0.7	1.11	0.64–1.90	0.7	1.1	0.79–1.53	0.6
South	1.06	0.86–1.30	0.6	0.87	0.56–1.34	0.5	1.11	0.87–1.42	0.4
West	1.23	0.96–1.56	0.1	0.77	0.46–1.30	0.3	1.19	0.90–1.59	0.2
Teaching hospital									
No	Ref			Ref			Ref		
Yes	0.94	0.78–1.12	0.5	0.85	0.58–1.23	0.4	0.84	0.68–1.04	0.11
Hospital beds									
0–99	Ref			Ref			Ref		
100–199	1.07	0.62–1.84	0.8	0.71	0.20–2.57	0.6	1.46	0.75–2.84	0.3
200–299	1.2	0.70–2.06	0.5	1	0.28–3.51	>0.9	1.57	0.81–3.05	0.2
300–399	1.31	0.76–2.24	0.3	1.36	0.39–4.68	0.6	1.71	0.88–3.31	0.11
400–499	1.12	0.65–1.92	0.7	1.11	0.32–3.88	0.9	1.75	0.90–3.42	0.1
500+	1.11	0.65–1.90	0.7	1.19	0.35–4.11	0.8	1.63	0.84–3.16	0.15
Prophylaxis regimen									
Nonguideline	Ref			Ref			Ref		
Guideline-adherent	0.83	0.74–0.93	**0.001**[a]	0.89	0.68–1.17	0.4	0.85	0.74–0.96	**0.012**[a]

Abbreviation: Ref, reference. Bold values are significant $p < 0.05$.

[a]No longer significant on sensitivity analysis of outpatient surgeries only.

4 | DISCUSSION

In this study, we aimed to identify trends in AUA guideline-adherent antimicrobial use over time and identify predictors of AUS complications using a large national database. This is the largest study of antimicrobial use in AUS surgery to our knowledge. Approximately 32% of patients experienced a complication, and 26% required surgical revision, consistent with reported rates from other large retrospective single-center and database studies.[5,16,17]

Besides complications coded as "other," infectious complications appear to account for the majority of surgical revision/removal events, which explains similar findings in these models. The exception is history of diabetes. Diabetes specifically was associated with a higher risk of infection and ED or inpatient readmission. This echoes results from a recent multinational study which demonstrated nearly three times the risk of infectious complications and four times the risk of device explantation in diabetic men who received AUA-adherent prophylactic regimens.[11] Older age also appears to be associated with a higher risk of any complication. Previous research on AUS insertion in elderly men suggests similar surgical revision rates as the overall population, however, 20% required deactivation in one study due to poor functional status or dementia.[18,19] We identified an increased risk of 3 month complications and infection with patients admitted postoperatively, but a lower risk of revision/removal. While the majority of AUS insertion patients are discharged the same day, admitted patients tend to be older and more medically complex.[20] Patients also may have been admitted due to intraoperative complications or earlier diagnosis of device issues, which preempts a later surgical event that was not caught in same-day discharge patients.

AUS infection and erosion events are typically caused by skin flora such as *Staphylococcus epidermidis* and *Staphylococcus aureus*, and others by Gram-negative bacilli such as *Proteus mirabilis* and *Escherichia coli* which may be associated with urine.[7,21] This knowledge has informed the most recent AUA Best Practice guidelines, but the foundation of recommendations for prosthesis prophylaxis comes primarily from the orthopedic literature.[10,17,22] There currently exists no consensus for the most optimal regimen.

Proponents for standardized professional antibiotic prophylaxis guidelines report decreased rates of resistant bacterial strains and costs.[23,24] However, critics argue that these recommendations may not be sufficient and actually cause harm for patients receiving genitourinary prostheses.[11,12,25,26] Notably, the European Urological Association no longer provides specific recommendations for prosthetics due to lack of high-level evidence for individual regimens.[27] The present study shows an increase in AUA guideline-adherent antimicrobial use from 2000 to 2020. This growth seems primarily due to the adoption of aminoglycoside + vancomycin. The high rate of methicillin-resistant organisms has likely driven the increase in vancomycin use compared to the slight downtrend in first generation cephalosporin use seen in the current study.[7] The development of other first line antimicrobials with more favorable toxicity profiles has limited widespread bacterial resistance to aminoglycosides, and gentamicin appears to be re-emerging as an attractive option due to its low cost and broad coverage.[28,29] Fluoroquinolones also saw decreased usage over the study period. This may be attributed to the US Food and Drug Administration (FDA) "black box" warning on fluoroquinolones issued in 2008 due to the risk of tendonitis and tendon rupture.[30]

Deviations from guideline recommendations are likely multifactorial and dependent on individual surgeon preferences, local antibiograms, and individual patient tolerances and culture sensitivities. In addition, some surgeons may routinely admit patients, while others plan to admit patients who are more medically complex or have complications intraoperatively. While most research on antimicrobial controversy in urologic prosthetics has been performed in penile prostheses, their findings can be extrapolated for the AUS. Some surgeons may elect to add antifungal coverage for patients with diabetes as they appear to be at higher risk of fungal infections in penile prostheses. Despite the FDA warning, the addition of a quinolone antibiotic has also been associated with decreased risk of complications when added to a certain guideline-based regimens.[11,26]

As guideline-adherence has increased over time, it is worth examining whether AUA guideline-adherence has translated to improvement in AUS postoperative outcomes. In our cohort, the use of guideline-adherent regimens appears to decrease the likelihood of any complication by 17% and revision/removal by 15% within 3 months. This benefit did not translate to a statistically significant reduction in 3-month infectious complication events. Interestingly, the beneficial effects of guideline-adherent regimens appeared to disappear on a sensitivity analysis of outpatient procedures only, which likely capture more uncomplicated AUS insertions. Our findings add to data suggesting that the AUA guidelines may not be suitable for all patients undergoing insertion of a urologic prosthesis. Additional factors such as choice of preoperative skin preparation and antimicrobial scrub, improvement in surgical techniques, cumulative surgeon knowledge, and better patient counseling may all have contributed to this trend and are beyond the scope of this study.[16,21,22]

Our study is not without limitations. The retrospective nature of our study and inherent limitations of the PHD, which captures only encounters at hospitals within the database, may underestimate the rate of complications. Inconsistencies and errors in medical billing may also affect the rate of reported complications compared to their actual incidence, which may explain the lack of association of guideline-adherence with complications. Although the PHD has been used extensively in national studies due to its representation of all regions in the United States, it is known to over-represent hospitals that are larger, in urban areas, and in the South.[14,35] Rationale for antibiotic regimen and perioperative wound/urine culture data was unknown. Data regarding surgical technique (e.g., perineal, penoscrotal) and antibiotic use following discharge was also not available. However, this is the largest cohort assessing real-world antimicrobial usage in AUS surgery and contributes to important discussions of antimicrobial stewardship and best practices in prosthesis surgery.

5 | CONCLUSIONS

Our evaluation of antimicrobial usage in AUS surgery using a large national database shows an increase in AUA guideline-adherent regimen use over the past two decades. This trend seems largely driven by increases in aminoglycoside and vancomycin use. While there were fewer complications and revisions were observed in the guideline-adherent patients, there was no significant association with decreased risk of infection within 3 months. Surgeons appear to be increasingly following recommendations from the AUA and other national bodies for antimicrobial prophylaxis for AUS surgery, however, further level 1 evidence should be obtained to demonstrate conclusive benefit of these regimens.

AUTHOR CONTRIBUTIONS

Helen H. Sun contributed to the design of the study, data acquisition, analysis and interpretation of data, drafting of the manuscript, and revisions for intellectual content. Michael Callegari contributed to the design of the study, analysis and interpretation of data, and drafting of the manuscript. Eric Zhou contributed to data acquisition and drafting of the manuscript. Stephen Rhodes contributed to the design of the study, data acquisition, analysis and interpretation of the manuscript, and revision of the manuscript for intellectual content. Aaron Brant contributed to the design of the study, and revision of the manuscript for intellectual content. Erin Jesse contributed to the design of the study and revision of the manuscript for intellectual content. Megan Prunty contributed to the design of the study and revision of the manuscript for intellectual content. Jonathan E. Shoag contributed to the design of the study, data acquisition, and final approval of the completed manuscript. Kyle Scarberry contributed to the revision of the manuscript for intellectual content, and final approval of the completed manuscript. Kirtishri Mishra contributed to the design of the study, interpretation of data, revision of the manuscript for intellectual content, and final approval of the completed manuscript. Shubham Gupta contributed to the design of the study, interpretation of data, revision of the manuscript for intellectual content, and final approval of the completed manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Jonathan E. Shoag had full access to all data used in the study and takes responsibility for the integrity of the data and accuracy of the data analysis. Research data are not shared.

ETHICS STATEMENT

This study received approval by our Institutional Review Board (IRB No. STUDY 20201207).

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REFERENCES

1. Koch GE, Kaufman MR. Male stress urinary incontinence. *Urol Clin North Am*. 2022;49(3):403-418. doi:10.1016/j.ucl.2022.04.005
2. Hester AG, Kretschmer A, Badlani G. Male incontinence: the etiology or basis of treatment. *Eur Urol Focus*. 2017;3(4-5):377-384. doi:10.1016/j.euf.2017.12.002
3. Srivastava A, Joice GA, Patel HD, Manka MG, Sopko NA, Wright EJ. Causes of artificial urinary sphincter failure and strategies for surgical revision: implications of device component survival. *Eur Urol Focus*. 2019;5(5):887-893. doi:10.1016/j.euf.2018.02.014
4. Suarez OA, McCammon KA. The artificial urinary sphincter in the management of incontinence. *Urology*. 2016;92:14-19. doi:10.1016/j.urology.2016.01.016

5. Shelton TM, Brimley S, Tsambarlis P, Hellstrom WJG. Current perspectives on complications of surgical treatments for male stress urinary incontinence. *Sexual Med Rev*. 2020;8(3):443-449. doi:10.1016/j.sxmr.2019.12.003
6. Linder BJ, de Cogain M, Elliott DS. Long-term device outcomes of artificial urinary sphincter reimplantation following prior explantation for erosion or infection. *J Urol*. 2014;191(3):734-738. doi:10.1016/j.juro.2013.08.089
7. Hofer MD, Gonzalez CM. Current concepts in infections associated with penile prostheses and artificial sphincters. *Urol Clin North Am*. 2015;42(4):485-492. doi:10.1016/j.ucl.2015.05.008
8. Lai HH, Boone TB. Complex artificial urinary sphincter revision and reimplantation cases—How do they fare compared to virgin cases? *J Urol*. 2012;187(3):951-955. doi:10.1016/j.juro.2011.10.153
9. Wolf JS, Bennett CJ, Dmochowski RR, Hollenbeck BK, Pearle MS, Schaeffer AJ. Best practice policy statement on urologic surgery antimicrobial prophylaxis. *J Urol*. 2008;179(4):1379-1390. doi:10.1016/j.juro.2008.01.068
10. Lightner DJ, Wymer K, Sanchez J, Kavoussi L. Best practice statement on urologic procedures and antimicrobial prophylaxis. *J Urol*. 2020;203(2):351-356. doi:10.1097/JU.0000000000000509
11. Rezaee ME, Towe M, Osman MM, et al. A multicenter investigation examining American Urological Association recommended antibiotic prophylaxis vs nonstandard prophylaxis in preventing device infections in penile prosthesis surgery in diabetic patients. *J Urol*. 2020;204(5):969-975. doi:10.1097/JU.0000000000001158
12. Swanton AR, Yafi FA, Munarriz RM, Gross MS. A critique of the American Urological Association penile prosthesis antibiotic prophylaxis guidelines. *J Sex Med*. 2021;18(1):1-3. doi:10.1016/j.jsxm.2020.10.010
13. *PINC AI™ Healthcare Data: Data That Informs and Performs (White Paper)*. PINC AITM Applied Sciences, Premier Inc.; 2022:13.
14. Higgins TL, Deshpande A, Zilberberg MD, et al. Assessment of the accuracy of using *ICD-9* diagnosis codes to identify pneumonia etiology in patients hospitalized with pneumonia. *JAMA Netw Open*. 2020;3(7):e207750. doi:10.1001/jamanetworkopen.2020.7750
15. Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models using lme4; 2014. doi:10.48550/ARXIV.1406.5823
16. Yafi FA, DeLay KJ, Stewart C, Chiang J, Sangkum P, Hellstrom WJG. Device survival after primary implantation of an artificial urinary sphincter for male stress urinary incontinence. *J Urol*. 2017;197(3 pt 1):759-765. doi:10.1016/j.juro.2016.08.107
17. Van der Aa F, Drake MJ, Kasyan GR, Petrolekas A, Cornu JN. The artificial urinary sphincter after a quarter of a century: a critical systematic review of its use in male non-neurogenic incontinence. *Eur Urol*. 2013;63(4):681-689. doi:10.1016/j.eururo.2012.11.034
18. O'Connor RC, Nanigian DK, Patel BN, Guralnick ML, Ellision LM, Stone AR. Artificial urinary sphincter placement in elderly men. *Urology*. 2007;69(1):126-128. doi:10.1016/j.urology.2006.09.021
19. Ballantyne CC, Sharma D, Rapp DE, Boatman KR, Krzastek SC, Costabile RA. Prevalence of cognitive impairment and sphincter misuse among men with artificial urinary sphincters. *Urology*. 2021;148:292-296. doi:10.1016/j.urology.2020.10.021
20. Dropkin BM, Sanders SC, Kavoussi M, et al. Same day discharge versus overnight observation protocols—similar outcomes following artificial urinary sphincter surgery. *Urology*. 2021;157:206-210. doi:10.1016/j.urology.2021.08.016
21. Magera JS, Inman BA, Elliott DS. Does preoperative topical antimicrobial scrub reduce positive surgical site culture rates in men undergoing artificial urinary sphincter placement. *J Urol*. 2007;178(4):1328-1332. doi:10.1016/j.juro.2007.05.146
22. Biardeau X, Aharony S, the AUS Consensus Group, Campeau L, Campeau L, Corcos J. Artificial urinary sphincter: report of the 2015 consensus conference: artificial urinary sphincter. *Neurourol Urodyn*. 2016;35(S2):S8-S24. doi:10.1002/nau.22989
23. Cai T, Verze P, Brugnolli A, et al. Adherence to European Association of Urology guidelines on prophylactic antibiotics: an important step in antimicrobial stewardship. *Eur Urol*. 2016;69(2):276-283. doi:10.1016/j.eururo.2015.05.010
24. Bell BG, Schellevis F, Stobberingh E, Goossens H, Pringle M. A systematic review and meta-analysis of the effects of antibiotic consumption on antibiotic resistance. *BMC Infect Dis*. 2014;14(1):13. doi:10.1186/1471-2334-14-13
25. Gross MS, Reinstatler L, Henry GD, et al. Multicenter investigation of fungal infections of inflatable penile prostheses. *J Sex Med*. 2019;16(7):1100-1105. doi:10.1016/j.jsxm.2019.05.003
26. Towe M, Andrianne R, Broderick G, et al. 028 adherence to the AUA penile prosthesis antibiotic prophylaxis guidelines in diabetic patients is associated with significantly higher risks of device infection. *J Sex Med*. 2020;17(suppl 1):S15. doi:10.1016/j.jsxm.2019.11.030
27. Bonkat G, Pickard R, Bartoletti R, et al. *Urological Infections*. European Association of Urology; 2018.
28. Bader MS, Loeb M, Leto D, Brooks AA. Treatment of urinary tract infections in the era of antimicrobial resistance and new antimicrobial agents. *Postgrad Med*. 2020;132(3):234-250. doi:10.1080/00325481.2019.1680052
29. Poulikakos P, Falagas ME. Aminoglycoside therapy in infectious diseases. *Expert Opin Pharmacother*. 2013;14(12):1585-1597. doi:10.1517/14656566.2013.806486
30. Tanne JH. FDA adds "black box" warning label to fluoroquinolone antibiotics. *BMJ*. 2008;337(a816):a816. doi:10.1136/bmj.a816

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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