Health Services Research

Institutional Micro-Cost Comparative Analysis of Reusable vs Single-use Cystoscopes With Assessment of Environmental Footprint

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OBJECTIVE To conduct a comparative cost analysis between single-use and reusable cystoscopes from a national healthcare system perspective and assess the environmental footprint.

METHODS Single-center micro-cost analysis of reusable vs single-use cystoscopes used institutional data. The cost breakdown included capital, reprocessing, repair, procedure, and environmental impact expenses. Data collection occurred in 2022, utilizing registered data, observations, and expert opinions. Depreciation was applied over 5 years for reusable cystoscopes and 8 years for the automated endoscope reprocessor. Deterministic sensitivity analyses gauged result robustness to input variations. Lastly, an assessment of the environmental footprint, focusing on water consumption and waste generation, was conducted.

RESULTS Per-procedure cost associated with reusable cystoscopes was €332.46 vs €220.19 associated with single-use, resulting in savings of €112.27. When projecting these costs per procedure with the number of procedures performed in 2022 (1186), comparing the costs of procedures performed in 1 year with reusable endoscopes (€394,295.86) to the costs of the exact number of procedures performed with disposable endoscopes (€261,149.37), a saving of €133,146.49 could be achieved. Additionally, after continuous use of single-use endoscopes, procedures were scheduled every 20 minutes instead of every 30 minutes. This adjustment allowed for 15 daily procedures instead of 10 while maintaining the same shift. This suggests potential advantages in terms of improved organizational impact and reduced waiting lists. Ultimately, the decreased environmental impact favored the adoption of single-use cystoscopes.

CONCLUSION Our study presents an opportunity for organizational development in response to the evolving external environment, considering user needs, market dynamics, and competition with other facilities. UROLOGY xx: xxx–xxx, xxxx.

Cystoscopy is one of the most utilized diagnostic endoscopic examinations in the field of urology aimed at visualizing the lower urinary tract.

Ambulatory cystoscopy, commonly done in outpatient settings, serves diverse purposes, including assessing patients with hematuria or lower urinary tract symptoms, as well as monitoring and preventing malignant tumors in the lower urinary tract. The procedure also encompasses the extraction of urinary devices post other endourological processes, like urethral or double-J ureteral stents. Notably, the primary emphasis is on diagnosing and tracking bladder tumors. Traditionally, reusable and sterilized instruments were utilized for ambulatory cystoscopy, necessitating meticulous reprocessing to ensure instrument integrity, and minimize infection risks. However, this reprocessing involves multiple phases, durations, and costs. Consequently, many urologists are increasingly adopting disposable sheaths to extend cystoscope lifespan and reduce staff expenses.[1]

In recent years, technological evolution has led to the advent of fully functional disposable cystoscopes on the market that display good image quality, active deflection, and maneuverability.[2] However, using a disposable cystoscope is generally associated with increased costs, raising concerns for healthcare decision-makers.[3]

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To elucidate the role of disposable cystoscopes, we quantified the costs associated with flexible cystoscopy procedures from a national healthcare system perspective and conducted a comparative cost analysis between single-use vs reusable cystoscopes. Moreover, we provided a comparison of the relative environmental footprint.

MATERIALS AND METHODS

A retrospective institutional analysis of reusable vs single-use cystoscopes was conducted which included a micro-costing analysis thanks to the collaboration with the Institutional management control department.

Data were collected from the calendar year 2022 based on:

- register data (repair cost, time, annual procedure volume, capital investment of equipment);
- observations (identification of capital equipment and equipment for reprocessing);
- procedure time, reprocessing time.

To calculate the costs per procedure, where necessary, the number of procedures performed in 2022 was considered. The cost analysis was segmented into various categories, encompassing capital, repair, reprocessing, procedure materials, operating room personnel costs, environmental impact, and overhead costs. As evident, for single-use endoscopes, expenses associated with repair and reprocessing were excluded from consideration. Each identified item related to the procedure was assigned a monetary value, and the average number of units used was then categorized, based on their intended purpose, into one of the aforementioned groups.

Capital

The per-procedure costs were determined by considering the capital investment for the acquisition of 20 reusable cystoscopes [10 Storz (Karl Storz, Tuttlingen, Germany) + 10 Olympus (Olympus, Norderstedt, Germany)], 1 endoscopic column (comprising a monitor, control unit, light source, and camera), and 2 sterilization centers (automated endoscope reprocessors) available in the urology department of the hospital. The depreciation period for reusable cystoscopes was set at 5 years, while the automated endoscope reprocessors were depreciated over 8 years, in line with established practices in the literature.[4] In the case of single-use endoscopes, only the device cost was considered as the capital cost.

Repair

All repairs conducted in 2022 have been meticulously considered in terms of both quantity and cost. These figures were then divided by the number of procedures conducted in the same year to ascertain the cost per procedure. The register data pertaining to the repairs of reusable cystoscopes during 2022 underwent descriptive analysis to estimate the availability and reliability of the reusable cystoscopes within the department.

Reprocessing

The costs associated with reprocessing were computed by considering the expenses linked to the initial disinfection phase (uniform for all reusable endoscopes) and the subsequent phase (which varies based on plasma gas or Ethylene Oxide reprocessing).

These costs were then adjusted based on the number of procedures performed to derive a cost per procedure. Additionally, the costs related to the personnel from the Operating Room Sterilization Services involved in the reprocessing procedure (see 2.4.) and the expense of the pressure gauge were also factored into the calculations.

Procedure Materials and Operating Room Personnel Costs

To conduct a more precise micro-cost analysis, all materials utilized during the procedure and the minute-based costs of personnel involved in the procedure were meticulously accounted for. The minute-based cost data for the resources utilized, including 1 doctor and 2 nurses, were extrapolated from the national contract data applied to our Institution's employees.

The detailed breakdown of all costs associated with procedures conducted with reusable endoscopes is presented in Supplementary Tables 1-2, while Supplementary Table 3 provides the equivalent details for procedures performed with single-use endoscopes.

Environmental Impact

Recognizing the growing significance of environmental impact in healthcare, we assessed the environmental footprint, specifically regarding water consumption and waste generation, associated with using reusable and single-use endoscopes, as illustrated in Table 1.

Overhead Cost

For a comprehensive analysis, an overhead cost of 20% was incorporated to cover expenses such as:

- The administration cost (including general administration, sending/receiving scopes for repair, and microbiological tests)
- The cost associated with training and educating healthcare staff in reprocessing (a complex multi-step process)
- Utilities related to water and electricity required for reprocessing and automated endoscope reprocessor.

To gauge the resilience of the base case result against variations in selected input parameters, deterministic sensitivity analyses were conducted. Specifically, key input parameters were varied by − 25%, − 50%, + 25%, and + 50% to assess their impact on the model's results.

Table 1. Environmental impact.

Water Usage	Average Water Usage per Procedure (liters)		Italian Average Water Costs	Total Costs
Reusable endoscopes	60		€ 0.0036	€ 0.22
Single-Use Endoscopes	0		€ 0.0036	€ -
Δ liters of H_20*				**-60 liters**
Δ €*				**-0.22 €**
Waste generation	Average Waste Usage per Procedure (Kg)	CO_2 Production (Kg)	Italian Average Waste Costs	Total Costs
Reusable endoscopes	6	36	€ 0.3470	€ 2.08
Single-use Endoscopes	3.5	21	€ 0.3470	€ 1.21

RESULTS

The micro-costing analysis was conducted using data gathered from 1186 cystoscopy procedures performed in 2022, specifically concerning reusable endoscopes. For single-use endoscopes, data were collected from procedures performed starting August 2023. In this context, the per-procedure total cost associated with reusable flexible cystoscopes amounted to €332.46, while it was €220.19 for single-use cystoscopes, resulting in a cost-saving of €112.27 (Δ costs) when comparing the 2 types of procedures, as illustrated in Table 2A.

As depicted in the waterfall diagram presented in Supplementary Figures 1-2, illustrating the incremental cost per procedure, the notable difference is primarily attributed to the costs associated with reprocessing (€82.00) and repairs (€13.83), both of which are unnecessary for single-use. Additionally, variations in material usage and time spent on resources during the procedure contribute to this difference. Despite the higher capital cost of single-use endoscopes (€130.00 vs €63.37), considering all costs associated with a single procedure, including hidden costs, the expense of procedures performed with reusable endoscopes is considerably higher than initially perceived.

The tornado diagram presented in Figure 1 illustrates the parameters with the most substantial impact on the cost per procedure in the deterministic sensitivity analysis. This analysis was conducted on the incremental costs between reusable and single-use, where each parameter was individually adjusted by − 25%, − 50%, + 25%, and + 50% to assess their influence on the model's results. The outcomes reveal a degree of robustness in the data, with all deterministic sensitivity analysis scenarios favoring single-use.

Moreover, in the assessment of the environmental impact of reusable and single-use endoscopes, as presented in Table 2A, the utilization of the latter results in a saving of approximately 60 liters of water per procedure (due to the omitted need for reprocessing), a reduction of about 3 kg of waste (attributed to the lack of reprocessing-related materials), and a decrease of approximately 15 kg of CO_2 emitted per procedure.

Table 2

(A) Δ Cost per Procedure	Reusable Endoscopes	Single-Use Endoscopes	
Capital	63.37 €	130.00 €	
Repair	13.83 €	0.00 €	
Reprocessing	82.20 €	0.00 €	
Procedure Materials	50.25 €	8.88 €	
Operating room personnel costs	65.10 €	43.40 €	
Environmental Impact associated	2.30 €	1.21 €	
Overhead costs*	53.87 €	36.70 €	
Procedure Total cost	**332.46 €**	**220.19 €**	
	Δ cost per Procedure	**-112.27 €**	
	H_20 Saving	**-60**	
	Waste Saving (kg)	**-3**	
	CO_2 Saving (kg)	**-15**	
(B) Δ Costs per 1-year Procedures			
No. Endoscopy procedures per year	1186		
	Reusable Endoscopes	Single-Use Endoscopes	Δ
Capital	75,157.97 €	154,180.00 €	79,022.03 €
Repair	16,400.71 €	0.00 €	-16,400.71 €
Reprocessing	97,493.64 €	0.00 €	-97,493.64 €
Procedure Materials	59,592.82 €	10,531.68 €	-49,061.14 €
Operating room personnel costs	77,208.60 €	51,472.40 €	-25,736.20 €
Environmental Impact associated	2726.14 €	1440.40 €	-1285.74 €
Overhead costs*	65,715.98 €	43,524.90 €	-22,191.08 €
Procedure Total cost	**394,295.86 €**	**261,149.37 €**	**-133,146.49 €**

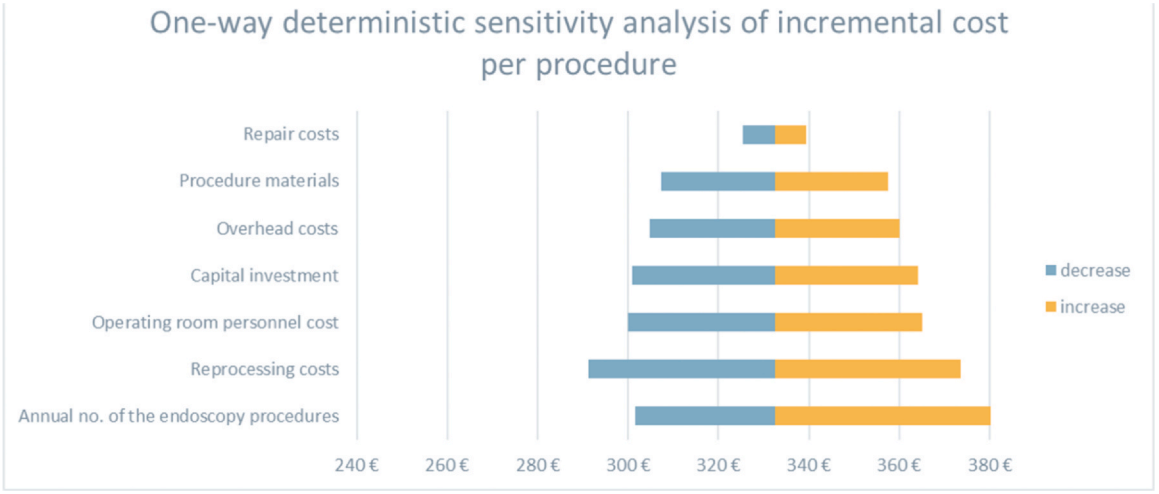

Figure 1. Tornado Diagram illustrating the parameters with the most substantial impact on the cost per procedure in the deterministic sensitivity analysis.

In the ultimate analysis, after defining the cost per procedure (reusable vs single-use), a decision was made to extrapolate these costs by multiplying them by the number of cystoscopy procedures performed in 2022. The aim was to assess the potential annual savings delta if only single-use endoscopes had been employed. As illustrated in Table 2B and Figure 2, when comparing the costs of procedures conducted in a year with reusable endoscopes (€394,295.86) to the costs of the same procedures performed with disposable endoscopes (€261,149.37), a significant saving of €133,146.49 could be realized in 1 year. If we extend the analysis to consider savings in terms of environmental impact per procedure for 1 year of procedures, the result is a saving of 71,160 liters of water, approximately 2965 kg less waste, and consequently, a reduction of − 17,790 kg of CO_2 emitted.

Analyzing the periods during which various reusable endoscopes were under repair without a replacement device reveals the following:

- Only 1/3 of the year (4 months) were all reusable cystoscopes available to the department.
- For 1 month (31 days) each year, 4-5 reusable cystoscopes were simultaneously unavailable due to repairs. This corresponds to 20%-25% of all the department's cystoscopes not being available at the same time.
- The department required repair for reusable cystoscopes 29 times in 2022, with a median downtime of 17 (IQR 10-20) days before the device was back in service.

As depicted in Supplementary Tables 1 and 3, the analysis indicates that procedures, after continuous use of single-use endoscopes, were scheduled every 20 minutes instead of every 30 minutes. This adjustment allowed for 15 daily procedures instead of 10 while maintaining the same shift. Additionally, standardizing the positioning of male and female patients in the supine position instead

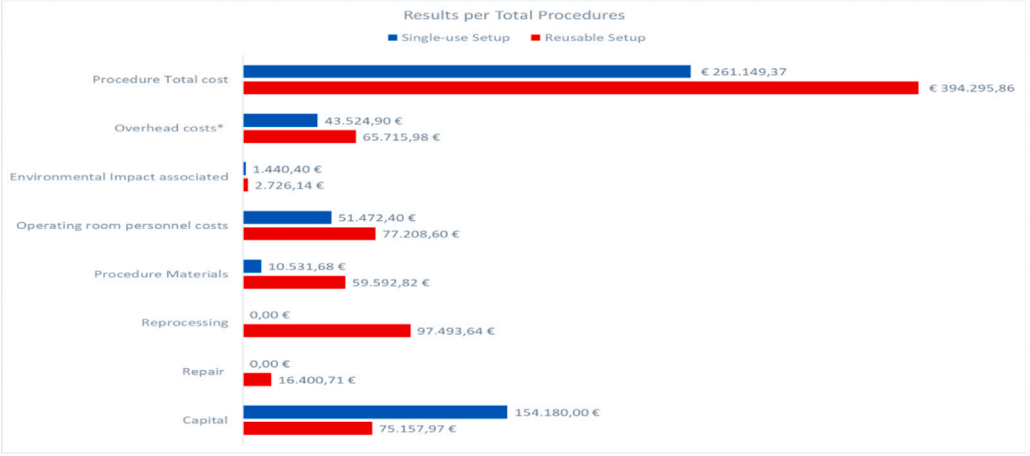

Figure 2. Δ costs per 1-year procedures.

of the gynecological position, using only flexible single-use cystoscopes, and streamlining downtime between patients contributed positively to the urology team's organizational impact, reducing waiting lists.

DISCUSSION

The present micro-costing single-institutional analysis conducted on 1186 cystoscopy procedures performed in 1-year time span found an advantage in costs and environmental impact from adopting single-use cystoscopes.

We acknowledge that assessing the cost-effectiveness of a single-use flexible cystoscope at a tertiary care center is not easy. Indeed, although some of the available experiences were designed in a rigorous manner, a paucity of them provided a cost-effectiveness study examining the implementation of a hospital-based transition to single-use cystoscopes.

For example, a 3-center, dual-arm post-market clinical trial randomized 102 patients to compare the single-use cystoscope (Ambu aScope) with standard-of-care flexible reusable cystoscopes used for outpatient ureteral stent removal. The trial showed comparable device success with significant time savings for single use and equivalent clinician satisfaction, but the authors were unable to account for costs.[5]

Micro-cost analyses of the economics of cystoscopy showed that there is a considerable contribution of capital equipment, maintenance, labor, and supplies to the cost of cystoscopy, with profitability highly dependent on the volume of cystoscopies performed for each cystoscope. Thus, one should expect that the cost-effectiveness of disposable cystoscopes will vary by clinic volume and site of practice.[3]

Let's explore the recent literature to understand the significance of €112.27 savings we observed per procedure performed with single-use cystoscopes at our institution. Assmus et al. initiated a 90-day trial period during which all encountered indications to the use of flexible cystoscope were provided with a disposable Ambu aScope. The authors performed a micro-costing analysis examining payor per case cost of the reusable flexible cystoscope (including servicing and processing) to the disposable units. Over the 90-day period, the authors encountered 84 cases where flexible cystoscopy was required. Per use cost of the reusable flexible cystoscope at their center was $272.41 vs $185.00 for the single use. After extrapolating the average case volume and failure rate (3 single-use failures/month, requiring reusable during the study time-span), the authors concluded that transition to predominately single-use scopes might result in $39,142.84 annual cost savings. In summary, per-use costs are less when a single-use flexible cystoscope is utilized at a high-volume tertiary care center.[6]

Within a prospective randomized comparison of reusable vs single-use cystoscopes for removal of double-J stents, including cost analysis, Alkhamees et al. found both disposable and reusable cystoscopes comparable regarding surgeons' and patients' satisfaction.

Within the 64 procedures performed in the study, with an average calculated cost per procedure of 509.4 US dollars for reusable cystoscopes vs a total cost per procedure for disposable cystoscopes of 533 US dollars, the authors concluded that disposable cystoscope was more cost-effective than reusable one.[7]

After gathering 10 institutions worldwide with experience on Isiris-α, Oderda et al. performed an analysis of the reported costs of double-J stent removal with Isiris-α, as compared to the traditional reusable equipment used in each institution. Isiris-α was more profitable in institutions where double-J stent removal is usually performed in the operative room, allowing the transfer of the procedure to the outpatient clinic, with a significant cost saving and operative room time saving to be allocated to other activities. Conversely, in institutions where stent removal was already performed in outpatient clinics, there was a slight cost difference in favor of reusable instruments.[8]

Kim et al. performed a retrospective micro-cost analysis of reusable cystoscopy at their institution. The cost analysis was divided into capital, maintenance, reprocessing, and labor.

The total annual costs per case for reusable and single-use cystoscopy were $149.06 and $245.57, respectively (costs were calculated in Canadian dollars). The costs of reusable cystoscopy decreased with the number of procedures per year and intersected the costs of single-use cystoscopes at 1265 procedures per year. Unfortunately, this analysis combined both inpatient and outpatient settings.[9]

A multicentric, prospective, observational study on 135 patients undergoing in-office ureteral stent removal with Isiris-α or a reusable Storz flexible cystoscope including a cost analysis showed that the in-office procedure performed with Isiris-α was more expensive (€137.8).

On the other hand, the reader should note that the costs relative to instrument turnover or disinfection remained unaccounted for.[10]

Young et al. performed a cost-comparison between the single-use Ambu aScope 4 cystoscope and reusable Olympus CYF-VHR and V2 cystoscopes in 2 different clinical settings: a high-volume multi-provider practice and a low-volume single-provider practice. At the high-volume multi-provider practice, per-case cost for reusable cystoscopy amounted to $65.98 compared to $227.18 for single-use cystoscopy, with reusable equipment being more cost-effective after 294 cystoscopies. At the low-volume single-provider practice, the per-case cost for reusable cystoscopy was $232.62 compared to $461.18 for single-use cystoscopy, with reusable equipment more cost-effective after 19 cases. Thus, based on their micro-costing analysis, per-case costs favored reusable cystoscopes.[11]

As anticipated while reporting previous research, the issue of the caseload is a complex one. Su et al. tried to evaluate the total cost of outpatient flexible cystoscopy associated with reusable device purchase, maintenance, and reprocessing and assessed potential cost benefits from the adoption of single-use flexible cystoscopes. For

ureteral stent removal procedures, the total cost per procedure using reusable cystoscopes (range $165-$1469) was higher than that using single-use devices ($244-$420), unless the annual procedure volume was sufficiently high relative to the number of reusable cystoscopes in the institutional fleet (≥ 350 for a practice with 10 reusable cystoscopes, ≥ 700 for 1 with 20 devices). The authors concluded that the cost of reprocessing reusable cystoscopes represents a large fraction of the total cost per procedure, especially for high-volume centers. Thus, adopting single-use cystoscopes for stent removal procedures might be cost-effective, especially for lower-volume facilities.[12]

A recent systematic review of all studies comparing the clinical outcomes of patients undergoing urological procedures with single-use endoscopes to those of patients treated with reusable endoscopes showed a shorter operating time associated with single-use flexible cystoscope use.

Overall, it also highlighted that single-use endoscopes' cost efficiency and environmental impact largely depend on the caseload and reprocessing facilities available within a given institution. Therefore, urologists can feel confident that whether they choose to "use" or "reuse" based on the financial and environmental implications, they can do so without negatively impacting patient outcomes.[13] Finally, it is important to note that with the introduction of single-use flexible cystoscopes at an institution, the pressure on the endoscopy suite can be reduced, thus avoiding typical delays in stent removals.[14] Our experience showed that continuous use of single-use endoscopes allowed for 15 daily procedures instead of 10 while maintaining the same shift, with implications on the waiting lists.

And What About the Environmental Impact?

In our analysis, the utilization of single-use endoscopes resulted in a saving per procedure of approximately 60 liters of water, about 3 kg of waste, and approximately 15 kg of CO_2 emitted, which corresponded in 1-year time span to 71,160 liters of water saved, approximately 2965 kg less waste, and a reduction of 17,790 kg of CO_2 emitted.

Kemble et al. analyzed the expected clinical lifecycle of single-use (Ambu aScope) and reusable (Olympus CYF-V2) flexible cystoscopes, from manufacture to disposal. The total estimated per-case carbon footprint of single-use and reusable devices was 2.40 and 0.53 kg CO_2, respectively, significantly different from what we estimated. This is probably why the authors concluded that, in their lifecycle analysis, the environmental impact of reusable flexible cystoscopes was markedly less than that of single-use cystoscopes.[15]

A single-center retrospective study evaluated the impact of the gradual replacement of reusable cystoscopes by the Ambu aScope single-use cystoscope (Ballerup, Denmark). While the cost of flexible cystoscopy performed with either a reusable or a disposable endoscope was the same (€196 vs €192, respectively), the amount of waste generated by reprocessing reusable and disposable cystoscopes was 800 and 200 g per procedure, respectively. Again, we admit these data are significantly different compared to our estimates. Conversely, water consumption for sterilization of the reusable cystoscope was 60 liters per procedure, which is very similar to our estimates, whereas no water consumption was required with single-use cystoscope. The authors concluded that a 100% transition to single-use cystoscopes would reduce waste generation and water consumption by 946.8 kg and 94.68 m^3, and we may agree with this.[16]

One limitation of our study is that we sought to only compare the per-use micro-costing analysis between reusable and disposable cystoscopes without evaluating the start-up costs or impact of inflation. Moreover, several other costs associated with recycling or disposing of single-use cystoscopes were not taken into account, which could include (1) financial costs—the actual monetary expenses involved in collecting, transporting, and processing the discarded scopes, including fees for specialized recycling services or waste management; (2) environmental impact—the ecological consequences of recycling or disposing of the scopes, such as energy consumption, emissions, and the potential release of hazardous materials during the recycling process; (3) resource utilization—the consumption of resources in the recycling process, including water, energy, and raw materials needed to break down and reprocess the materials of the single-use scopes; (4) technological infrastructure—investments in infrastructure for recycling facilities or waste disposal systems, which may require ongoing maintenance and upgrades; (5) regulatory compliance—costs associated with adhering to environmental regulations and standards governing the proper disposal and recycling of medical equipment. Understanding and quantifying these costs in future efforts will be essential for a comprehensive assessment of single-use cystoscopes' environmental footprint and economic implications throughout their lifecycle.

Finally, we acknowledge that regional or institutional differences in the analyzed costs limited the generalization of our findings.

On the other hand, considering the available literature, our study highlights the potential sustainability of the costs of single-use cystoscopes, providing further evidence that urology teams should perform institutional cost assessments when comparable novel technologies are introduced. Finally, we underline the exciting results observed in terms of environmental footprint within the setting of our analysis, with single-use cystoscopes leading to reduced waste generation, water consumption, and CO_2 emission.

CONCLUSION

Our institutional analysis indicates that a key concern among policymakers—potential higher costs linked to single-use endoscopes—is counterbalanced by organizational improvements and the elimination of reprocessing

and repairs. Furthermore, the study underscores the positive impact on the organizational efficiency of cystoscopy procedures, notably reducing waiting lists. The growing acceptance of disposable endoscopes not only resolves cost issues but also positions our study as an opportunity for organizational development in light of the changing external environment. This approach considers user needs, market dynamics, and competition with other facilities.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Acknowledgment. None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.urology.2024.03.023.

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