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Article

# Tray Application Versus the Standard Surgical Procedure: A Prospective Evaluation

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## Abstract

(1) Background: trays are surgery-specific sets of required materials and medical devices, assembled in consultation between manufacturer and user, and provided in a sterile package.; (2) Methods: in a high-volume urological center performing 11,920 operations/procedures annually (2023), we prospectively evaluated the effect of trays compared with the standard approach in a comparative study of 64 operations conducted between October 29 and November 30, 2024. The primary endpoints were the amount of operating room (OR) waste (volume/cm<sup>3</sup>, weight/g) and setup time (minutes). The secondary endpoint was the workflow assessment by nursing staff, rated on a numerical score (0–10) across seven relevant domains.; (3) Results: for endourological procedures, setup time was reduced by 35%, operating room (OR) waste by 34%, and waste volume by 19.0%. Workflow was positively rated with a mean score of 9.75/10. For major open procedures, setup time was reduced by 43%, waste weight by 24.8%, and waste volume by 32%. Workflow was positively rated with a mean score of 8.9/10; (4) Conclusions: Trays have a sustainable and significant impact on reducing OR waste, save nursing staff preparation time, and facilitate improved workflow in the operating room.

**Keywords:** sustainability; green hospital; surgical tray; operation room waste; workflow analysis

## 1. Introduction

Hospitals are among the largest producers of waste within the healthcare sector, which substantially contributes to environmental pollution and economic costs. In Germany, hospitals generate approximately 6 kg of waste per bed per day, resulting in a total of 1.2 million tons of hospital waste annually. The use of disposable products and their packaging waste is continuously increasing. In addition to waste generation, each patient consumes around 500 liters of water and 110 kWh of energy per day, calculated from both electricity and thermal energy. On an annual basis, this corresponds to estimated energy costs of €4 billion in German hospitals, accompanied by a considerable CO<sub>2</sub> footprint. The healthcare sector alone is responsible for approximately 5–10% of total CO<sub>2</sub> emissions [1,2].

German hospitals are currently under substantial economic pressure. In our model hospital, comprising four sites with 1,223 beds, annual waste generation amounts to 1,476 tons, of which packaging waste accounts for 13.2% (Otto, personal communication). Since the average disposal costs of €575,000 per year represent only about 0.1% of total hospital expenses, waste management is often considered of minor relevance from a procurement perspective. Consequently, “green procurement”

tends to have a low priority in decision-making, as cost-driven purchasing practices frequently contradict the implementation of sustainable procurement policies.

Work science studies have demonstrated that the level of acceptance by staff affected by reorganization is the decisive factor for achieving efficient, effective, and economically viable workflows. Therefore, it is of central importance not only to assess time savings and sustainability effects but also to consider the acceptance of the new tray logistics among staff members [3]. This present study aimed to investigate the impact of introducing trays on both waste reduction and workflow efficiency in the operating room (OR).

## 2. Materials and Methods

The study was initiated on October 29, 2024, and recruitment ended on November 30, 2024. A total of 64 operations were analyzed, with 20 scrub nurses/assistants participating. Among them, 8 were in training as surgical technical assistants (OTA), and 12 were certified nurses. All procedures were performed by a single highly experienced surgeon (>30,000 personally conducted operations). Endourological procedures were carried out in OR 6, while open surgical procedures were performed in the adjacent OR 7. The storage facility for medical products and trays was located within 10 meters of both ORs. The setup, draping, instruments, and medical devices—including irrigation and drainage systems—were standardized for both transurethral resection (TUR) and open surgery, in consultation with the OR management, tray manufacturer, and medical device suppliers. All disposable materials, except for abdominal swabs and gauze compresses, were included in the measurements.

All participating staff members (n=20 operating theatre assistants, nurses) were informed and instructed in advance. The study was presented at the OR coordination meeting, and nursing staff provided their consent to participate. Patient rights were not affected, and therefore no insurance or patient consent was required. The ethics committee of Rheinland Klinikum Neuss GmbH was informed prior to the study, and an approving statement was obtained.

Responsible persons were designated: Katharina Hansen (Head of OR Nursing) and the study director Prof. Dr. Thomas Otto (Director of the Urology Center). Setup time was measured in seconds using a stopwatch by the scrub nurse involved in the case. Waste weight and volume were recorded directly after surgery by Prof. Otto.

Two standard preparations (TUR procedure and major open surgery) were compared with two corresponding trays specifically designed for the respective procedures. The study was conducted prospectively and comparatively.

The following variables were documented to characterize the study groups: surgery date, patient (age, sex), type of surgery, circulating nurse, scrub nurse, surgeon, incision-to-suture time, anesthesia preparation, and anesthesia recovery.

The primary endpoints were the amount of waste (volume and weight) and setup time (seconds/minutes). In addition, relief of OR staff was assessed through a subjective evaluation of workflow by participating scrub nurses, rated on a numerical scale from 0 (poor) to 10 (excellent). To determine waste volume, the OR waste bag was placed in a rectangular container (length: 36 cm, width: 30 cm) and compressed with a standardized pressure of 3 kg. The height of the waste in cm was then measured. Waste volume was calculated as 36 cm × 30 cm × height (cm). The weight of the waste bag in the container was measured using a precision scale (accuracy ±3 g). The container and empty bag weighed 1,366 g, which was subtracted from the total measured weight.

Setup time (minutes/seconds) was measured by stopwatch. It included the time needed to transport materials from the OR storage to the operating room and the time until all materials were arranged on the instrument table. The OR storage was located within sight of the operating room. Workflow evaluation was performed by the nursing staff using a standardized questionnaire, completed immediately after surgery.

Data analysis was performed using SPSS software, version 29.0.2.0 (IBM, USA). The normal distribution of metric data was tested using the Shapiro–Wilk test. As some variables were not

normally distributed, non-parametric test procedures were applied. Group comparisons between the tray and standard groups were performed using the Mann–Whitney U test. Workflow evaluation (ordinal score 0–10) was also assessed with the Mann–Whitney U test. The significance level was set at  $\alpha = 0.05$ . P values  $< 0.05$  were considered statistically significant.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. TUR Procedures

As shown in Table 1, the perioperative times and study-relevant outcomes differed between the TUR standard group (n = 22) and the TUR tray group (n = 20). In the TUR standard group, the mean anesthesia preparation time was 18.05 minutes, anesthesia recovery time was 7.33 minutes, and incision-to-suture time was 30.1 minutes. The study-relevant outcomes showed a mean setup time of 8.59 minutes, a mean waste weight of 355.57 g, and a mean waste volume of 0.3751 m<sup>3</sup>. In the TUR tray group, the mean anesthesia preparation time was 21.3 minutes, anesthesia recovery time was 6.3 minutes, and incision-to-suture time was 26.1 minutes. The study-relevant outcomes demonstrated a reduced setup time of 5.49 minutes, a reduced waste weight of 234.66 g, and a reduced waste volume of 0.3078 m<sup>3</sup>. Compared with the standard group, the use of trays resulted in a 35% reduction in setup time, a 34% reduction in waste weight, and an 18% reduction in waste volume (Table 2). Workflow evaluation by the OR nursing staff was rated very positively, with a mean overall score of 9.75/10, and detailed assessments across seven workflow-related items confirmed consistently high ratings (Table 3).

**Table 1.** Comparison of procedures, perioperative times, and waste parameters between the TUR standard and tray groups.

|                                          | TUR standard group<br>(n = 22) | TUR tray group<br>(n = 20) |
|------------------------------------------|--------------------------------|----------------------------|
| <b>Types of procedures performed (n)</b> |                                |                            |
| bladder tumor resections                 | 13                             | 15                         |
| prostate resections                      | 7                              | 4                          |
| anastomosis resection                    | 1                              | 2                          |
| urethral incisions                       | 2                              | 1                          |
| suprapubic catheter placement            | 1                              | 1                          |
| other procedures                         | 3                              | 1                          |
| <b>Mean times (min)</b>                  |                                |                            |
| Anesthesia preparation                   | 18.05                          | 21.3                       |
| Anesthesia recovery                      | 7.33                           | 6.3                        |
| Incision-to-suture time                  | 30.1                           | 26.1                       |
| <b>Study-relevant mean values</b>        |                                |                            |
| Setup time (min)                         | 8.59                           | 5.49                       |
| Waste weight (g)                         | 355.57                         | 234.66                     |
| Waste volume (m <sup>3</sup> )           | 0.3751                         | 0.3078                     |

TUR standard group: A total of 27 procedures were performed in 22 patients; in 5 patients, more than one procedure was conducted. TUR tray group: A total of 20 procedures were performed in 20 patients; in 4 patients, more than one procedure was conducted.

**Table 2.** TUR: comparison between the standard group and the tray group.

| Variable              | Standard (n = 22) | Tray (n = 20)  | Reduction (%) | P-value |
|-----------------------|-------------------|----------------|---------------|---------|
| Setup time (min)      | 8.99 ± 1.32       | 5.49 ± 0.88    | -35%          | <0.001  |
| Packaging weight (g)  | 355.57 ± 34.2     | 234.66 ± 25.3  | -34%          | <0.001  |
| Packaging volume (m³) | 0.3751 ± 0.045    | 0.3078 ± 0.036 | -18%          | 0.002   |
| Workflow score (0–10) | 7.85 ± 0.72       | 9.75 ± 0.16    | +24%          | <0.001  |

p<0.05 significant.

**Table 3.** Workflow evaluation of TUR by OR nursing staff (n = 20).

| Item                                              | Mean Score (0–10) |
|---------------------------------------------------|-------------------|
| Trays make my work easier                         | 10.0              |
| Trays improve workflow in the OR                  | 10.0              |
| Trays reduce my workload                          | 9.95              |
| Trays save time                                   | 9.90              |
| Trays can contribute to a less hectic environment | 10.0              |
| Trays reduce packaging waste                      | 9.25              |
| Trays make an important ecological contribution   | 9.15              |

3.1. Major Open Surgery Procedures

As shown in Table 4, the perioperative times and study-relevant outcomes differed between the standard group (n = 12) and the tray group (n = 10). In the standard group, the mean anesthesia preparation time was 15.4 minutes, anesthesia recovery time was 12.1 minutes, and incision-to-suture time was 79.5 minutes. The study-relevant outcomes showed a mean setup time of 24.45 minutes, a mean waste weight of 1,111.49 g, and a mean waste volume of 0.781 m³. In the tray group, the mean anesthesia preparation time was 24.2 minutes, anesthesia recovery time was 18.7 minutes, and incision-to-suture time was 95.0 minutes. The study-relevant outcomes demonstrated a reduced setup time of 14.07 minutes, a reduced waste weight of 835.00 g, and a reduced waste volume of 0.539 m³. Compared with the standard group, tray use resulted in a 43% reduction in setup time, a 25% reduction in waste weight, and a 32% reduction in waste volume (Table 5). Workflow evaluation by the OR nursing staff was rated positively, with a mean overall score of 8.91/10. Detailed assessments across seven workflow-related items are summarized in Table 6.

**Table 4.** Comparison of open major surgery procedures, perioperative times, and waste parameters between the standard and tray groups.

|                                                     | Standard group<br>(n = 12) | Tray group<br>(n = 10) |
|-----------------------------------------------------|----------------------------|------------------------|
| <b>Types of procedures performed (n)</b>            |                            |                        |
| Prostate adenomectomies                             | 4                          | 2                      |
| Radical retropubic prostatectomy                    | 1                          | 2                      |
| Relaparotomy                                        | 1                          | -                      |
| Pyeloplasty (Da Vinci-assisted)                     | 1                          | -                      |
| Burch colposuspension/sacropexy (Da Vinci-assisted) | 1                          | -                      |
| Nephroureterectomy                                  | 1                          | -                      |
| Renal tumor resection                               | 1                          | 2                      |
| Cystectomies                                        | 2                          | 4                      |
| <b>Mean times</b>                                   |                            |                        |
| Anesthesia preparation (min)                        | 15.4                       | 24.2                   |
| Anesthesia recovery (min)                           | 12.1                       | 18.7                   |
| Incision-to-suture time (min)                       | 79.5                       | 95                     |

Study-relevant mean values

|                   |          |       |
|-------------------|----------|-------|
| Setup time (min)  | 24.45    | 14.07 |
| Waste weight (g)  | 1,111.49 | 835   |
| Waste volume (m³) | 0.781    | 0.539 |

Table 5. Open major surgery: comparison between the standard group and the tray group.

| Variable              | Standard (n = 12) | Tray (n = 10) | Reduction (%) | p-value |
|-----------------------|-------------------|---------------|---------------|---------|
| Setup time (min)      | 24.45 ± 3.1       | 14.07 ± 2.3   | −43%          | <0.001  |
| Packaging weight (g)  | 1111.49 ± 121.4   | 835.00 ± 89.6 | −25%          | 0.004   |
| Packaging volume (m³) | 0.781 ± 0.06      | 0.539 ± 0.07  | −32%          | <0.001  |
| Workflow score (0–10) | 7.98 ± 0.84       | 8.91 ± 0.41   | +12%          | 0.011   |

p<0.05 significant.

Table 6. Workflow evaluation of open major surgery procedures by operating room (OR) nursing staff (n = 20).

| Item                                              | Mean Score (0–10) |
|---------------------------------------------------|-------------------|
| Trays make my work easier                         | 8.99              |
| Trays improve workflow in the OR                  | 9.21              |
| Trays reduce my workload                          | 9.21              |
| Trays save time                                   | 9.21              |
| Trays can contribute to a less hectic environment | 9.21              |
| Trays reduce packaging waste                      | 8.82              |
| Trays make an important ecological contribution   | 8.04              |

4. Discussion

The scientific literature on OR waste, particularly packaging waste in the operating room, remains insufficient. Reported percentages and extrapolations are often presented without specifying actual case numbers. Details on specific procedures and frequency are not provided. Extrapolations from a few observed cases are scientifically questionable, and methodologies for assessing OR waste are generally not described. Furthermore, the limited literature is usually based on economic perspectives, with observations conducted primarily by personnel unfamiliar with the OR environment [4–7].

In our study, we systematically compared the use of trays versus the standard approach in a prospective and scientifically reproducible design, encompassing 64 consecutive operations. All procedures were performed in a standardized manner by a single highly experienced surgeon. Data collection was carried out at all levels by trained professionals from the central OR of a tertiary care hospital. Patient-related variability was accounted for by comparing anesthesia preparation and recovery times as well as incision-to-suture times. This ensured comparability of workflows across different patient conditions. Importantly, no selection bias was introduced among OR staff; both trainees and highly experienced nurses were involved to reflect routine practice and ensure a normal distribution of experience levels in workflow evaluation. All 64 surgeries were performed by the same surgeon, and subsequent measurements of waste weight and volume were also conducted by a single person to minimize systematic error.

Primary endpoints included waste amount (volume and weight), setup time, and workflow evaluation by OR staff. The secondary endpoint was the assessment of tray use on workflow (score 0 = poor to 10 = excellent). According to the study director, direct explanations and hands-on instructions for OR and cleaning staff in handling disposable medical products are essential. For this study, direct onsite measurements by the designated surgeon and nurse were indispensable. Workflow questionnaires were completed immediately postoperatively in the OR by the involved staff; memory-based protocols were excluded.

### *Evaluation of Tray Composition*

The TUR tray was rated as optimal by the nursing staff, with no reported deficiencies. In contrast, the major surgery tray was considered incomplete, lacking certain items such as a bladder catheter, abdominal swabs, and a bladder syringe. One of the two wash bowls and one green abdominal drape were deemed unnecessary. In addition, the suction tip was too large, and the dissection swabs should be smaller. From the surgeon's perspective, the bladder syringe in the TUR tray appeared of inferior quality, as plastic parts broke easily and the irrigation inflow could not be interrupted. Nevertheless, the remaining instruments were considered satisfactory in handling and usability. For the major surgery tray, additional standard medical products could be included; overall, materials were rated as good in handling and usability. For both trays, it is essential that the composition of plastics be declared to enable proper recycling. The evaluation of tray contents highlights the necessity of intensive collaboration between OR staff, surgeons, and tray providers.

### *Staff Satisfaction*

Trays had the greatest impact on staff satisfaction among OR personnel. In times of staffing shortages and competition for qualified staff, this represents a critical advantage. Across all evaluation parameters, trays were rated as very good by assisting OR staff. The overall score was 9.75/10 for the TUR group and 8.9/10 for major open surgeries.

### *Time Savings*

The use of trays demonstrably increased productivity, with setup times reduced by 35% in smaller endourological procedures and by 43% in major open surgeries. The resulting time savings can be utilized to improve communication and planning between surgeons and OR staff. Contrary to claims frequently made by hospital economists, improved daily OR throughput could not be demonstrated in our model. No significant difference in the total number of procedures per day was observed. However, the time savings were perceived very positively by nursing staff as a reduction of workload stress (score 9.2–10.0). Furthermore, trays facilitated adherence to regular working hours, representing another competitive advantage in staff recruitment.

### *Waste Reduction*

The use of trays led to demonstrable reductions in packaging waste. In TUR procedures, waste weight was reduced by 34%, whereas reductions in waste volume were most pronounced in major open surgeries (32%). Cost savings from reduced waste disposal should not be overstated. In our model hospital, total waste disposal costs for 1,485 tons of waste per year amount to €537,000. The primary benefit of trays lies in their ecological contribution by reducing the overall volume of hospital waste.

### *Impact on Recycling Options Through Tray Configuration*

From both a staff satisfaction and waste reduction perspective, trays are clearly advantageous. Since trays are not pre-defined by manufacturers but assembled in consultation with hospitals and users, they can be tailored to support ecological circular economy goals. By disclosing the material composition of tray components, environmentally sustainable configurations can be achieved. Avoiding fluorinated or chlorinated plastics and plasticizers, while favoring polyethylene and polypropylene-based materials, enables the production of reusable pyrolysis oil through chemical recycling (German Patent Application No. 10 2025 110 802.1).

### *Benefits for Manufacturers and Users of Trays*

The proven and significant advantages of trays contribute to brand development and provide competitive benefits for both providers and users. Hospitals can position themselves as "Green

Hospitals,” while tray providers influence the adoption of environmentally sustainable medical products. Thus, tray manufacturers play a decisive role in product selection across suppliers, with implications for both ecological and economic outcomes.

## 5. Conclusions

Significant improvements were achieved in all primary endpoints (setup time, packaging weight, and packaging volume) across both surgical categories with the use of trays. Time savings were particularly pronounced in major open surgeries, with a 43% reduction in setup time ( $p < 0.001$ ). Workflow evaluation was also significantly improved, with endourological procedures achieving a nearly optimal score of 9.75/10.

The implementation of trays provides ecological, economic, and organizational benefits that are statistically proven.

**Author Contributions:** Conceptualization, WE, JC, SW and TO; methodology, WE and TO; software, DB; validation, WE, JC, SW.; formal analysis, DB and TO; investigation, DB and TO.; resources, DB and TO; data curation, DB and TO; writing—original draft preparation, DB and TO; writing—review and editing, WE, DB and TO; visualization, TO; supervision, WE and TO; project administration, WE, JC and TO. All authors have read and agreed to the published version of the manuscript.

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**Informed Consent Statement:** no patient data was involved.

**Data Availability Statement:** The datasets generated and analysed during the current study are not publicly available due to data protection regulations, but are available from the corresponding author on reasonable request.

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## Abbreviations

The following abbreviations are used in this manuscript:

OR Operating room

TURTransurethral resection

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