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Improving Compliance with Biomedical Waste Management Practices in a Tertiary Trauma Care Hospital of Delhi: A Pre- and Post-Intervention Study

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ABSTRACT

Background: Compliance with biomedical waste (BMW) management guidelines is essential for infection control, occupational safety, and regulatory adherence. Despite established rules, gaps in segregation and documentation persist, particularly in high-intensity settings such as trauma care hospitals.

Objectives: To assess baseline compliance with biomedical waste management practices using a structured checklist, implement a targeted training and awareness intervention, and evaluate changes in compliance following the intervention.

Methods: A prospective interventional study was conducted in a 259-bedded tertiary trauma care hospital in Delhi. Compliance with BMW management practices was assessed using a structured checklist during a one-month pre-intervention period (November 2025). This was followed by a multi-modal intervention comprising staff training sessions and display of educational posters. Post-intervention compliance was assessed over one month. Pre- and post-intervention compliance scores were compared.

Results: Overall, compliance improved from 62.4% in the pre-intervention phase to 88.7% post-intervention. Significant improvement was observed in segregation at source, labelling, use of color-coded bins, and documentation practices.

Conclusion: Structured training and visual reinforcement using posters significantly improved compliance with biomedical waste management practices. Regular audits using checklists combined with continuous training can sustainably enhance compliance in tertiary trauma care hospitals.

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INTRODUCTION

Biomedical waste (BMW) management is an integral component of healthcare delivery systems, directly influencing patient safety, occupational health, and environmental protection. Biomedical waste includes any waste generated during the diagnosis, treatment, or immunization of human beings, as well as waste produced during related research activities or the production and testing of biologicals.[1] Owing to its infectious, toxic, and injurious potential, improper handling of biomedical waste can result in serious public health consequences, including transmission of blood-borne infections, needle-stick injuries, and environmental contamination.[2]

Recognizing these risks, the Government of India enacted the Bio-Medical Waste Management Rules, 2016, which provide a comprehensive regulatory framework for segregation, collection, storage, transportation, treatment, and disposal of biomedical waste.[1] The rules emphasize segregation of

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waste at the point of generation into designated color-coded categories, maintenance of daily records, regular training of healthcare workers, and continuous monitoring of compliance. Despite the existence of clear legal provisions, compliance with biomedical waste management practices remains inconsistent across healthcare facilities in India.[3,5]

India's expanding healthcare infrastructure, increasing patient load, and growing reliance on disposable medical products have contributed to a steady rise in the volume of biomedical waste generated by hospitals.[4] Several studies have documented gaps in knowledge, attitude, and practices related to biomedical waste management among healthcare personnel, particularly in tertiary care settings.[5,6,8] These gaps are often attributed to inadequate training, high staff turnover, workload pressures, and lack of continuous monitoring mechanisms.

Tertiary trauma care hospitals represent a particularly challenging environment for biomedical waste management. Such hospitals manage critically injured patients requiring emergency interventions, invasive monitoring, frequent surgical procedures, and prolonged intensive care unit (ICU) stays. These factors contribute not only to increased quantities of biomedical waste but also to greater complexity in waste segregation and handling.[7,9] Operating theatres and ICUs, which generate a substantial proportion of infectious and sharp waste, are recognized as high-risk areas for lapses in biomedical waste management practices.[15,16]

While availability of infrastructure such as color-coded bins and waste treatment facilities is essential, evidence suggests that compliance with biomedical waste management practices depends largely on human behaviour and system reinforcement.[10,11] Periodic training alone may not be sufficient to ensure sustained compliance, particularly in high-pressure clinical environments. Studies have shown that audit-and-feedback mechanisms, use of structured checklists, and visual reminders at the point of care can significantly improve adherence to infection control and waste management protocols.[12,13]

Checklists serve as simple yet powerful tools for standardizing practices, identifying deviations, and promoting accountability among healthcare workers.[18] When used regularly, they enable objective assessment of compliance and provide actionable feedback to both frontline staff and hospital administrators. Visual reinforcement through posters complements training efforts by offering real-time guidance, especially in settings with frequent rotation of resident doctors and contractual housekeeping staff.[11]

Despite the recognized importance of audits and training, there is limited published evidence from India evaluating the effectiveness of structured checklist-based interventions combined with training and visual reinforcement in improving biomedical waste management compliance, particularly in tertiary trauma care hospitals. Most available studies are cross-sectional in nature and focus on knowledge and attitudes rather than measurable changes in compliance over time.[5,8,14]

In this context, the present study was planned to assess baseline compliance with biomedical waste management practices in a tertiary trauma care hospital using a structured checklist, implement a targeted multi-component intervention comprising staff training and educational posters, and evaluate the impact of the intervention on compliance levels. By comparing pre- and post-intervention compliance, the study aims to generate evidence on practical, scalable strategies for strengthening biomedical waste management systems in high-acuity healthcare settings.

MATERIALS AND METHODS

This prospective interventional study was conducted in a 259-bedded tertiary trauma care hospital in Delhi, comprising emergency services, inpatient wards, 60 ICU beds, and six OTs. The study aimed to assess compliance with BMW management practices, implement a structured intervention, and evaluate its impact on compliance levels. The study design followed a pre- and post-intervention approach.

Baseline compliance assessment was carried out over a one-month pre-intervention period from 1 November 2025 to 30 November 2025. During this phase, biomedical waste management practices were evaluated daily across selected hospital areas including inpatient wards, ICUs, operating theatres, emergency department, and procedure rooms. Compliance assessment was performed using a structured checklist developed in accordance with the Bio-Medical Waste Management Rules, 2016, and standard infection control guidelines.

Table 1: Area-wise compliance comparison before and after intervention.

Area	Pre-intervention (%) Mean ± SD	Post-intervention (%) Mean ± SD	Mean difference (%)	*p*-value
Wards	64.1 ± 6.2	89.3 ± 4.8	25.2	<0.001
ICUs	60.5 ± 7.4	90.1 ± 4.5	29.6	<0.001
Operating theatres	58.2 ± 8.1	87.6 ± 5.6	29.4	<0.001
Emergency	66.8 ± 5.9	88.4 ± 5.0	21.6	<0.001

Table 2: Checklist item-wise compliance comparison.

Checklist item	Pre-intervention (%)	Post-intervention (%)	χ^2 value	*p*-value
Segregation at source	65.0	92.5	18.6	<0.001
Correct use of color-coded bins	70.2	95.4	16.2	<0.001
Proper sharps disposal	72.1	96.0	14.9	<0.001
Labelling of BMW bags	48.6	85.7	22.4	<0.001
Daily BMW documentation maintained	55.3	90.2	20.1	<0.001
Use of PPE by waste handlers	60.8	88.9	15.7	<0.001

The compliance checklist consisted of 15 items covering key domains of biomedical waste management, including availability and correct use of color-coded bins, segregation at source, sharps disposal practices, labelling and sealing of waste bags, use of personal protective equipment by waste handlers, maintenance of documentation, and safe storage and handover of biomedical waste. Each checklist item was scored as compliant (score of 1) or non-compliant (score of 0). Compliance scores were calculated as percentages for individual areas and for the hospital overall.

Following completion of the baseline assessment, a multi-component intervention was implemented during the first week of December 2025. The intervention included structured training sessions for healthcare workers (doctors, nurses, and paramedical staff) and housekeeping personnel. Training focused on biomedical waste categories, segregation principles, occupational hazards, regulatory requirements, and documentation practices. In addition, visually reinforced educational posters illustrating correct segregation practices and color-coding were displayed prominently in wards, ICUs, operating theatres, nursing stations, and waste collection areas. Supervisory reinforcement was provided through daily monitoring rounds by infection control staff during the intervention period.

Post-intervention compliance assessment was conducted over a one-month period from 1 January 2026 to 31 January 2026, using the same checklist and methodology as the pre-intervention phase. Compliance data were recorded daily, compiled, and averaged to determine post-intervention compliance levels.

Data analysis was descriptive in nature. Compliance scores were expressed as percentages, and pre- and post-intervention compliance levels were compared to assess improvement attributable to the intervention. Pre- and post-intervention compliance scores were compared using paired t-tests for continuous variables and the McNemar test for categorical checklist items. A *p-value* of <0.05 was considered statistically significant. The study involved no direct patient contact and utilized routine quality assurance data; therefore, formal ethical committee approval was not required. Confidentiality of institutional data was maintained throughout the study period.

RESULTS

Overall Compliance with Biomedical Waste Management Practices During the pre-intervention phase (November 2025), the mean overall compliance with biomedical waste (BMW) management practices was 62.4% ± 6.8. Following implementation of the structured training module and visual reinforcement measures, mean compliance during the post-intervention phase (January 2026) increased to 88.7% ± 5.2.

Comparison of pre- and post-intervention compliance scores using a paired t-test demonstrated a statistically significant improvement in overall compliance (mean difference: 26.3 percentage points; $t = 14.2$; $p < 0.001$).

Area-wise Compliance: Pre- and Post-Intervention Comparison

Area-wise compliance scores were compared using paired analysis across wards, ICUs, operating theatres, and the emergency department. All clinical areas demonstrated statistically significant improvement following the intervention.

Checklist Item-Wise Compliance Analysis

Compliance with individual checklist components was analyzed using the McNemar test for paired categorical data. Significant improvement was observed across all critical checklist items after the intervention.

Effect Size of the Intervention

The magnitude of improvement in overall compliance was quantified using Cohen's d, which showed a large effect size (d = 1.85), indicating that the intervention had a strong and meaningful impact on biomedical waste management practices.

DISCUSSION

The present study demonstrates that compliance with biomedical waste (BMW) management practices in a

tertiary trauma care hospital can be significantly improved through a structured, low-cost, multi-modal intervention comprising checklist-based audits, targeted training, and visual reinforcement using posters. The baseline overall compliance of 62.4% observed during the pre-intervention phase reflects suboptimal adherence to BMW management protocols, a finding consistent with earlier Indian studies conducted in tertiary care settings.[5,6,8] Such gaps are particularly concerning in trauma care hospitals, where the volume and hazardous nature of biomedical waste are substantially higher.

Following the intervention, overall compliance increased to 88.7%, with the improvement being statistically significant ($p < 0.001$) and associated with a large effect size. This magnitude of change indicates that the intervention produced not only statistical significance but also meaningful operational improvement. Similar studies have reported improvements in BMW compliance following educational and audit-based interventions, underscoring the importance of continuous training and monitoring in sustaining correct practices.[10,13]

Area-wise analysis revealed that ICUs and OTs had lower baseline compliance compared to wards and the emergency department. This finding is expected, as ICUs and OTs operate under high time pressure, manage critically ill patients, and generate large quantities of infectious waste, increasing the likelihood of segregation and documentation lapses.[15,16] Importantly, these areas demonstrated the greatest absolute improvement post-intervention, suggesting that targeted training and visual cues are particularly effective in high-risk and high-intensity clinical environments.

Item-wise analysis using McNemar testing highlighted that labelling of BMW bags and maintenance of daily documentation were the weakest components during the pre-intervention phase. Poor documentation has been repeatedly identified as a neglected aspect of BMW management, despite being a regulatory requirement under the Bio-Medical Waste Management Rules, 2016.[1,6] The significant post-intervention improvement in documentation practices observed in this study reflects enhanced awareness of regulatory obligations and improved accountability among healthcare workers.

Segregation at source and correct use of color-coded bins showed marked improvement following the intervention, achieving compliance levels exceeding 90%. These findings reinforce the role of visual reinforcement, as posters placed at points of waste generation served as immediate decision-support tools for staff. Visual aids have been shown to be particularly effective in settings with frequent staff rotation, such as resident doctors and contractual housekeeping personnel, where repeated formal training may not always be feasible.[11,12]

The use of a structured checklist proved to be a key strength of this intervention. Beyond its role as an assessment tool, the checklist functioned as a standard against which staff could align their practices. Checklist-based audits facilitate objective measurement, enable feedback, and promote integration of BMW management into routine quality and safety activities.[18] The paired analytical approach used in this study further strengthens the evidence by demonstrating that observed improvements were attributable to the intervention rather than random variation.

Overall, the findings suggest that improving BMW management compliance does not necessarily require resource-intensive solutions. Instead, systematic audits, focused training, and simple visual tools can bring about substantial and measurable improvements. Such interventions are particularly relevant for public sector tertiary hospitals in India, where resource constraints coexist with high patient loads and complex clinical workflows.

Strengths

This study has several notable strengths. First, it employed a prospective pre- and post-intervention design with daily audits over defined time periods, allowing robust comparison of compliance before and after the intervention. Second, the use of a standardized, rule-based checklist ensured objective and reproducible assessment of BMW management practices. Third, the study included multiple high-risk hospital areas, including ICUs and operating theatres, enhancing the relevance of the findings for tertiary trauma care settings. Finally, the application of appropriate analytical statistical tests strengthened the validity of the conclusions.

Limitations

The study also has certain limitations. It was conducted in a single tertiary trauma care hospital, which may limit generalizability to other healthcare settings. The post-intervention assessment covered only one month, and the long-term sustainability of improved compliance was not evaluated. Observer bias during compliance audits cannot be completely ruled out, although the use of a structured checklist helped minimize subjectivity. Additionally, the study focused on process compliance and did not assess downstream outcomes such as reduction in waste volume, cost savings, or occupational injury rates.

CONCLUSION

This interventional study demonstrates that compliance with biomedical waste management practices in a tertiary trauma

care hospital can be significantly improved through the use of structured checklists, targeted training modules, and visual reinforcement using posters. The intervention resulted in statistically and operationally significant improvements across all hospital areas, particularly in ICUs and operating theatres. Regular audits combined with continuous education and visual reminders represent a practical, scalable, and cost-effective strategy for strengthening biomedical waste management systems. Adoption of such quality-improvement approaches can enhance regulatory compliance, occupational safety, and environmental protection in high-acuity healthcare settings.

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