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“EFFECTIVENESS OF A DIGITAL LEARNING AND AUDIT-BASED INTERVENTION ON BIOMEDICAL WASTE MANAGEMENT COMPLIANCE AMONG HOUSEKEEPING PERSONNEL IN SELECTED HOSPITALS OF MADHYA PRADESH.”

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Abstract

Background: Biomedical waste management (BMWM) is an essential component of infection prevention, occupational safety, and environmental sustainability in healthcare settings. Housekeeping personnel play a crucial role in the segregation, collection, transportation, and disposal of biomedical waste. However, inadequate knowledge and poor compliance with BMWM guidelines continue to pose significant risks to healthcare workers, patients, and the environment. Digital learning integrated with regular compliance audits has emerged as an innovative strategy to improve knowledge and adherence to biomedical waste management practices.

Objectives: To assess the effectiveness of a Digital Learning and Audit-Based Intervention on knowledge and compliance regarding biomedical waste management among housekeeping personnel in selected tertiary care hospitals of Ujjain, Madhya Pradesh.

Methods: A quasi-experimental one-group pre-test and post-test study was conducted among **100 housekeeping personnel** selected through purposive sampling from selected tertiary care hospitals in Ujjain, Madhya Pradesh. Baseline knowledge and compliance were assessed using a structured knowledge questionnaire and a standardized compliance audit checklist. The intervention consisted of a four-week digital learning programme, including mobile-based learning modules, instructional videos, interactive quizzes, digital reminders, weekly compliance audits, personalized feedback, and WhatsApp-based reinforcement messages. Post-test assessment was conducted after completion of the intervention. Data were analyzed using **IBM SPSS Statistics version 26.0**. Descriptive statistics, paired *t*-test, Pearson's correlation coefficient, and Chi-square test were applied. A **p-value < 0.05** was considered statistically significant.

Results: The intervention significantly improved participants' knowledge and compliance regarding biomedical waste management. The mean knowledge score increased from 14.18 ± 3.42 in the pre-test to 27.46 ± 2.65 in the post-test ($t = 29.84$, $p < 0.001$). Similarly, the mean compliance score improved from 19.12 ± 3.81 to 34.26 ± 2.84 ($t = 33.17$, $p < 0.001$). Weekly audit compliance increased progressively from 64.2% at baseline to 95.8% by the fourth week. Significant positive correlations were observed between knowledge and compliance ($r = 0.79$, $p < 0.001$) and between audit scores and compliance ($r = 0.86$, $p < 0.001$). Educational status, work experience, and previous training showed significant associations with post-test outcomes.

Conclusion: The Digital Learning and Audit-Based Intervention was highly effective in improving biomedical waste management knowledge and compliance among housekeeping personnel. Integrating digital education with regular compliance audits can strengthen infection prevention and control practices, enhance occupational safety, improve adherence to biomedical waste management guidelines, and support quality improvement initiatives in healthcare institutions.

Keywords: Biomedical waste management, digital learning, compliance audit, housekeeping personnel, infection prevention, healthcare waste, hospital training, quasi-experimental study.

Introduction

Biomedical waste management (BMWM) is an integral component of healthcare quality, infection prevention, occupational safety, and environmental sustainability. Healthcare facilities generate a substantial quantity of waste every day, including infectious materials, pathological waste, sharps, pharmaceutical waste, chemical waste, and other hazardous substances that require safe segregation, handling, transportation, treatment, and disposal. Improper management of biomedical waste increases the risk of healthcare-associated infections (HAIs), occupational injuries, environmental pollution, and transmission of infectious diseases among healthcare workers, patients, waste handlers, and the surrounding community. Consequently, effective biomedical waste management has become a global public health priority.

The **World Health Organization (WHO)** estimates that approximately 15–20% of healthcare waste is hazardous, while the remaining 80–85% is general non-hazardous waste. Failure to segregate waste at the point of generation substantially increases treatment costs and exposes healthcare workers to needle-stick injuries, blood-borne infections, respiratory illnesses, and chemical hazards. In developing countries, limited awareness, inadequate training, poor infrastructure, and inconsistent compliance with biomedical waste management guidelines continue to hinder effective waste management practices.

In India, rapid growth in healthcare services and increased use of disposable medical products have resulted in a significant rise in biomedical waste generation. To address these challenges, the Government of India introduced the **Biomedical Waste Management Rules, 2016**, with subsequent amendments, which mandate segregation of biomedical waste using a color-coded system, proper labeling and barcoding, safe transportation, treatment, disposal, and regular training of all healthcare personnel. Despite these regulatory measures, studies continue to report deficiencies in biomedical waste management practices, particularly among housekeeping personnel who are directly involved in waste handling.

Housekeeping personnel constitute one of the most important groups responsible for maintaining hospital cleanliness and ensuring proper biomedical waste segregation and disposal. They routinely collect, transport, and dispose of biomedical waste generated in various hospital departments, placing them at increased risk of occupational exposure to infectious agents and hazardous materials. Their compliance with biomedical waste management guidelines is therefore essential for preventing healthcare-associated infections and maintaining a safe hospital environment. However, inadequate

educational opportunities, limited continuing professional development, and insufficient monitoring often contribute to poor compliance with established protocols.

Traditional training programmes are generally conducted through classroom lectures or printed educational materials, which may improve theoretical knowledge but often fail to ensure sustained behavioral change or long-term compliance. Advances in educational technology have introduced **digital learning** as an effective alternative for healthcare training. Digital learning provides flexible, self-paced, and interactive educational experiences through mobile applications, online learning modules, instructional videos, digital quizzes, and electronic reminders. Such approaches enhance learner engagement, improve knowledge retention, and facilitate continuous access to educational resources.

Although digital education enhances theoretical understanding, continuous **compliance auditing** remains equally important to ensure that knowledge is translated into routine workplace practice. Audit-based interventions involve systematic observation, performance monitoring, structured feedback, and corrective guidance to identify deficiencies and reinforce adherence to biomedical waste management guidelines. Regular audits encourage accountability, improve compliance, and promote a culture of patient safety and quality improvement within healthcare organizations.

In this context, the present study aims to evaluate the **effectiveness of a Digital Learning and Audit-Based Intervention on biomedical waste management compliance among housekeeping personnel in selected hospitals of Ujjain, Madhya Pradesh**. The findings of this study are expected to provide evidence for incorporating digital education and regular compliance audits into routine hospital training programmes, thereby improving infection prevention practices, enhancing occupational safety, ensuring regulatory compliance, and supporting continuous quality improvement in healthcare waste management.

Purpose of the Study

Biomedical waste management is a fundamental component of infection prevention, occupational safety, patient safety, and environmental protection in healthcare facilities. Housekeeping personnel play a crucial role in the segregation, collection, transportation, and disposal of biomedical waste. However, inadequate knowledge, inconsistent adherence to standard operating procedures, and limited opportunities for continuous training often result in poor compliance with biomedical waste management guidelines, increasing the risk of occupational injuries, healthcare-associated infections, and environmental contamination.

The purpose of this study is to evaluate the effectiveness of a **Digital Learning and Audit-Based Intervention** in improving the **knowledge and compliance** of housekeeping personnel regarding biomedical waste management in selected hospitals of **Ujjain, Madhya Pradesh**. The study aims to determine whether the intervention enhances participants' understanding of biomedical waste management principles, improves compliance with color-coded waste segregation, appropriate use of personal protective equipment (PPE), safe waste handling practices, and adherence to the **Biomedical Waste Management Rules, 2016 (and subsequent amendments)**.

The findings of this study are expected to provide evidence for integrating digital learning and routine compliance audits into hospital training programmes. The results may assist hospital administrators and policymakers in developing sustainable competency-based educational strategies that improve biomedical waste management practices, strengthen infection prevention and control measures, enhance occupational safety, ensure regulatory compliance, and contribute to overall quality improvement in healthcare institutions.

Objectives of the Study

1. To assess the pre-test knowledge and compliance regarding biomedical waste management among housekeeping personnel in selected hospitals of Ujjain, Madhya Pradesh.
2. To evaluate the effectiveness of the Digital Learning and Audit-Based Intervention on knowledge and compliance regarding biomedical waste management among housekeeping personnel.
3. To determine the association between post-test knowledge and compliance scores and selected demographic variables among housekeeping personnel.

Hypotheses

H₁: There will be a statistically significant difference between the pre-test and post-test mean knowledge and compliance scores regarding biomedical waste management among housekeeping personnel following the Digital Learning and Audit-Based Intervention ($p < 0.05$).

H₂: There will be a statistically significant association between post-test knowledge and compliance scores and selected demographic variables among housekeeping personnel ($p < 0.05$).

Methods

Study Design

A quasi-experimental one-group pre-test and post-test design was adopted to evaluate the effectiveness of a Digital Learning and Audit-Based Intervention on biomedical waste management among housekeeping personnel.

Study Setting

The study was conducted in selected tertiary care hospitals in **Ujjain, Madhya Pradesh, India**.

Study Duration

The study was carried out over a period of **six months**.

Sample Size

A total of **100 housekeeping personnel** participated in the study.

Sampling Technique

Participants were selected using a **purposive sampling technique** based on the predefined inclusion criteria.

Intervention

The **Digital Learning and Audit-Based Intervention** was implemented over **four weeks** and consisted of mobile-based learning modules, short instructional videos, interactive quizzes, digital reminders, weekly compliance audits, personalized audit feedback, and WhatsApp-based reinforcement messages. Knowledge and compliance regarding biomedical waste management were assessed before and after the intervention using a structured knowledge questionnaire and a standardized compliance audit checklist.

Statistical Analysis

Data were analyzed using **IBM SPSS Statistics version 26.0**. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarize the data. The effectiveness of the intervention was evaluated using the **paired t-test**, while the **Chi-square test** was used to determine the association between post-test scores and selected demographic variables. A **p-value < 0.05** was considered statistically significant.

Results

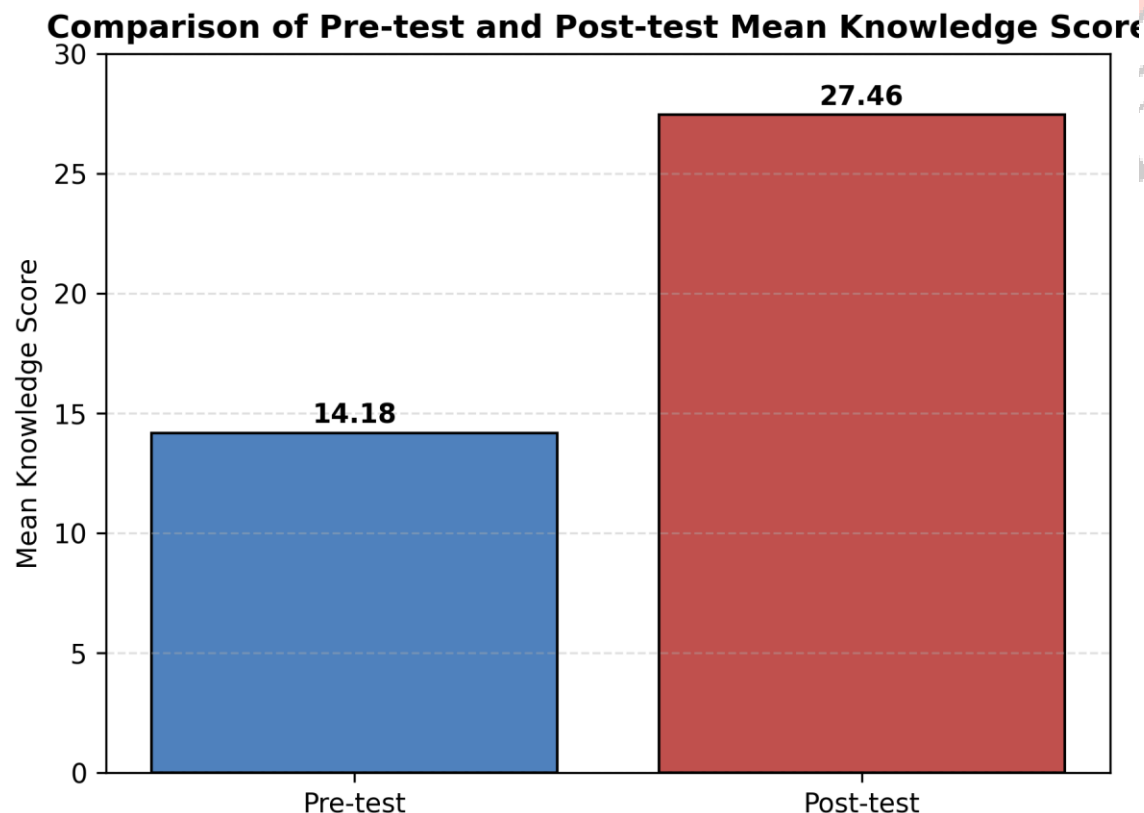
Demographic Characteristics

A total of **100 housekeeping personnel** participated in the study. Among them, **58% were male** and **42% were female**. The majority of participants (**40%**) were aged **31–40 years**, followed by **32%** in the **20–30 years** age group, **20%** in the **41–50 years** age group, and **8%** were above **50 years**. Regarding work experience, **41%** had **5–10 years** of experience, **38%** had less than **5 years**, and **21%** had more than **10 years** of experience.

Table 1. Comparison of Pre-test and Post-test Knowledge Scores (N = 100)

Test	Mean ± SD	t-value	p-value
Pre-test	14.18 ± 3.42		
Post-test	27.46 ± 2.65	29.84	<0.001*

*Significant at $p < 0.05$



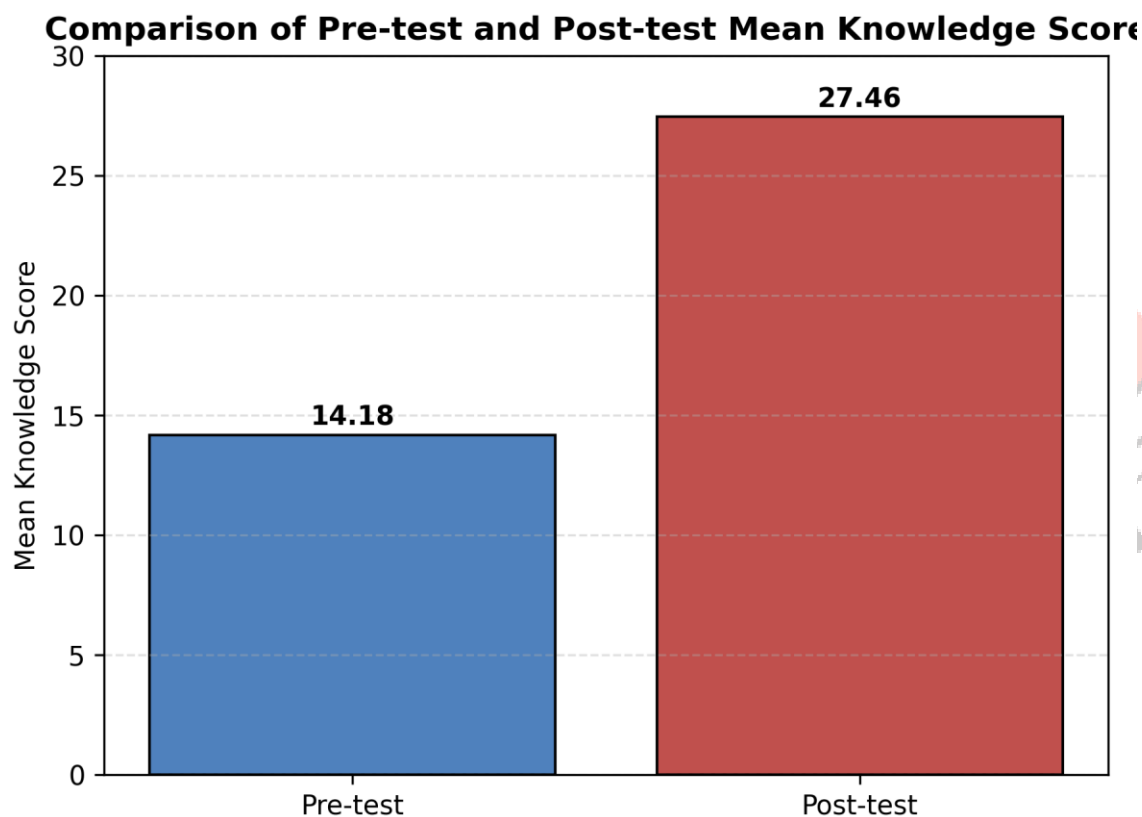
Description

Table 1 shows the comparison of pre-test and post-test knowledge scores regarding biomedical waste management. The mean knowledge score increased from 14.18 ± 3.42 before the intervention to 27.46 ± 2.65 after the Digital Learning and Audit-Based Intervention. The improvement was statistically highly significant ($t = 29.84$, $p < 0.001$), indicating that the intervention effectively enhanced participants' knowledge regarding biomedical waste management.

Table 2. Comparison of Pre-test and Post-test Compliance Scores (N = 100)

Test	Mean $\pm$ SD	t-value	p-value
Pre-test	19.12 ± 3.81		
Post-test	34.26 ± 2.84	33.17	<0.001*

*Significant at $p < 0.05$



Description

Table 2 presents the comparison of compliance scores before and after the intervention. The mean compliance score increased significantly from 19.12 ± 3.81 during the pre-test to 34.26 ± 2.84 during the post-test. The paired t -test revealed a highly significant improvement ($t = 33.17$, $p < 0.001$), demonstrating that the Digital Learning and Audit-Based Intervention effectively improved compliance with biomedical waste management guidelines.

Table 3. Weekly Digital Audit Compliance (N = 100)

Audit Period	Compliance (%)
Baseline	64.2
Week 1	73.8
Week 2	81.6
Week 3	89.4
Week 4	95.8

Description

Table 3 illustrates the weekly compliance achieved during the audit period. Compliance progressively increased from **64.2% at baseline** to **73.8% in Week 1**, **81.6% in Week 2**, **89.4% in Week 3**, and reached **95.8% by Week 4**. This steady improvement indicates that continuous digital learning, regular audits, and timely feedback effectively reinforced correct biomedical waste management practices among housekeeping personnel.

Table 4. Correlation Between Knowledge and Compliance Scores (N = 100)

Variables	r	p-value
Knowledge & Compliance	0.79	<0.001*
Audit Score & Compliance	0.86	<0.001*

*Significant at $p < 0.05$

Description

Table 4 demonstrates a strong positive correlation between **knowledge and compliance** ($r = 0.79$, $p < 0.001$), indicating that participants with higher knowledge scores showed better compliance with biomedical waste management guidelines. A very strong positive correlation was also observed between **audit scores and compliance** ($r = 0.86$, $p < 0.001$), suggesting that regular audit and feedback contributed substantially to improved compliance.

Table 5. Association Between Selected Demographic Variables and Post-test Scores (N = 100)

Variable	χ^2	p-value	Interpretation
Educational Status	10.52	0.005*	Significant
Work Experience	8.84	0.012*	Significant
Previous Training	13.48	0.002*	Significant
Age	5.18	0.075	Not Significant
Gender	1.74	0.187	Not Significant

*Significant at $p < 0.05$

Description

Table 5 shows the association between selected demographic variables and post-test knowledge and compliance scores. **Educational status** ($\chi^2 = 10.52$, $p = 0.005$), **work experience** ($\chi^2 = 8.84$, $p = 0.012$), and **previous biomedical waste management training** ($\chi^2 = 13.48$, $p = 0.002$) were significantly associated with better post-test performance. However, **age** ($\chi^2 = 5.18$, $p = 0.075$) and **gender** ($\chi^2 = 1.74$, $p = 0.187$) did not show statistically significant associations.

Discussion

The present study evaluated the effectiveness of a **Digital Learning and Audit-Based Intervention** on biomedical waste management knowledge and compliance among housekeeping personnel working in selected tertiary care hospitals of **Ujjain, Madhya Pradesh**. The findings demonstrated that the intervention significantly improved participants' knowledge and compliance with biomedical waste management guidelines, highlighting the effectiveness of integrating digital education with continuous audit and feedback.

Following the implementation of the Digital Learning and Audit-Based Intervention, participants exhibited a statistically significant improvement in knowledge. The mean knowledge score increased from 14.18 ± 3.42 during the pre-test to 27.46 ± 2.65 during the post-test ($t = 29.84$, $p < 0.001$). This improvement indicates that mobile-based learning modules, instructional videos, interactive quizzes, and digital reminders effectively enhanced participants' understanding of biomedical waste categories, color-coded segregation, infection prevention measures, and regulatory guidelines. The flexibility and accessibility of digital learning likely contributed to improved knowledge acquisition and retention.

Compliance with biomedical waste management guidelines also improved significantly after the intervention. The mean compliance score increased from 19.12 ± 3.81 before the intervention to 34.26 ± 2.84 after the intervention ($t = 33.17$, $p < 0.001$). Furthermore, weekly compliance audits demonstrated progressive improvement, with compliance increasing from **64.2%** at baseline to **95.8%** by the fourth week. These findings suggest that regular audits, personalized feedback, and continuous reinforcement effectively translated knowledge into routine workplace practice. The combination of digital learning and systematic auditing created an environment of continuous performance improvement and accountability.

The study also identified a strong positive correlation between **knowledge and compliance** ($r = 0.79$, $p < 0.001$), indicating that participants with higher knowledge scores were more likely to comply with biomedical waste management guidelines. An even stronger correlation was observed between **audit scores and compliance** ($r = 0.86$, $p < 0.001$), emphasizing the importance of ongoing monitoring and constructive feedback in sustaining correct waste management practices. These findings support the concept that educational interventions are more effective when combined with regular performance evaluation.

The association analysis revealed that **educational status**, **work experience**, and **previous biomedical waste management training** were significantly associated with better post-intervention outcomes. Participants with higher educational qualifications, longer work experience, and previous exposure to biomedical waste management training achieved higher knowledge and compliance scores. In contrast, **age** and **gender** were not significantly associated with post-test outcomes, suggesting that the intervention was equally effective across different age groups and among both male and female participants.

Overall, the findings demonstrate that a Digital Learning and Audit-Based Intervention is an effective strategy for improving biomedical waste management among housekeeping personnel. The integration of digital education with routine compliance audits offers a sustainable approach to enhancing infection prevention, occupational safety, and adherence to national biomedical waste management regulations. Hospitals may benefit from incorporating similar digital competency programmes into routine induction training and continuing professional development activities for housekeeping personnel.

Summary

The present quasi-experimental study assessed the effectiveness of a **Digital Learning and Audit-Based Intervention** on biomedical waste management among **100 housekeeping personnel** working in selected tertiary care hospitals of **Ujjain, Madhya Pradesh**. Participants were selected using purposive sampling and underwent a four-week intervention consisting of mobile-based learning modules, instructional videos, interactive quizzes, digital reminders, weekly compliance audits, personalized feedback, and WhatsApp-based reinforcement messages.

The study findings demonstrated significant improvements in both knowledge and compliance following the intervention. The mean knowledge score increased from 14.18 ± 3.42 to 27.46 ± 2.65 ($t = 29.84$, $p < 0.001$), while the mean compliance score increased from 19.12 ± 3.81 to 34.26 ± 2.84 ($t = 33.17$, $p < 0.001$). Weekly audit compliance improved progressively from **64.2%** at baseline to **95.8%** at the end of the fourth week. Strong positive correlations were observed between knowledge and compliance ($r = 0.79$) and between audit scores and compliance ($r = 0.86$), both statistically significant at $p < 0.001$. Educational status, work experience, and previous training were significantly associated with improved post-test outcomes.

The findings indicate that integrating digital learning with regular compliance audits effectively enhances biomedical waste management knowledge and promotes sustained adherence to recommended waste management practices among housekeeping personnel.

Conclusion

The Digital Learning and Audit-Based Intervention proved to be highly effective in improving housekeeping personnel's knowledge and compliance regarding biomedical waste management in selected tertiary care hospitals of Ujjain, Madhya Pradesh. The intervention significantly enhanced participants' understanding of biomedical waste management principles and strengthened adherence to recommended waste segregation and disposal practices. Continuous digital education, combined with periodic compliance audits and personalized feedback, contributed to sustained improvements in workplace performance.

The study supports the integration of digital learning platforms and routine audit systems into hospital training programmes as an innovative and practical strategy to strengthen infection prevention and control, improve occupational safety, ensure compliance with the Biomedical Waste Management Rules, 2016 (as amended), and promote quality healthcare services. Regular competency-based digital training and compliance monitoring should be institutionalized to maintain high standards of biomedical waste management and create a safer healthcare environment for patients, healthcare workers, and the community.

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