TPM Vol. 32, No. S3, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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DESIGN AND DEVELOPMENT OF A 3D PRINTED DRUG AND EQUIPMENT TRAY (SADET) TO FACILITATE UNASSISTED INTUBATION IN CRITICAL CARE SCENARIOS

DR. MANOJ ADITYA B [1] ; DR. MRUNALINI M N [2],
DR. RAMYAA DHANASEKARAN[3]

[1] POST GRADUATE, DEPARTMENT OF ANAESTHESIOLOGY, SAVEETHA MEDICAL COLLEGE, SIMATS, CHENNAI

[2] ASSISTANT PROFESSOR, DEPARTMENT OF ANAESTHESIOLOGY, SAVEETHA MEDICAL COLLEGE, SIMATS, CHENNAI

[3]SENIOR LECTURER, DEPARTMENT OF PROSTHODONTICS AND CROWN & BRIDGE, SREE BALAJI DENTAL COLLEGE & HOSPITAL, CHENNAI, INDIA

Abstract

Background:
Unassisted endotracheal intubation in emergency or resource-limited environments places immense cognitive and operational demands on anesthesiologists, often causing delays or errors due to disorganized equipment and drug arrangements.

Objective:
To design, develop, and evaluate the Situational Airway Drug & Equipment Tray (SADET) — a low-cost, 3D-printed device to improve ergonomic layout, speed, and safety during unassisted intubation.

Study Design:
Prospective, simulation-based crossover usability study with iterative design and evaluation.

Sample Size:
Fifteen qualified anesthesiologists participated. Each performed two runs with the standard setup and two with SADET (30 runs per setup).

Methods:
● Design Phase: Needs assessment (interviews with >10 anesthesiologists) to identify workflow barriers, design modelling and 3D printing.
● Evaluation Phase: Participants completed two simulated unassisted intubation runs with each setup, using standardized airway kits and drug vials.
● Metrics Recorded: Setup time, intubation time, drug/equipment retrieval time, drug identification errors, and satisfaction ratings.

Results:
SADET improved setup time by 64%, reduced drug/equipment retrieval times by 54%, shortened total intubation time by 39%, and eliminated all drug identification errors versus baseline. Satisfaction scores increased from 2.8/5 to 4.7/5.

Conclusion:
SADET significantly improved efficiency, safety, and workflow in simulated unassisted intubations. It is affordable, reproducible, and adaptable for various clinical environments.

1. INTRODUCTION

Unassisted intubations are common in trauma, rural, and resource-limited settings. Assembling drugs and equipment in a disorganized fashion can critically delay airway control and increase errors. An ergonomic organizing system tailored to procedure flow can minimize these risks. With 3D printing, clinicians can create affordable, workflow-specific solutions. This study describes the design and simulation-based evaluation of SADET in a sample of fifteen anesthesiologists, each performing two runs with each setup.

2. MATERIALS AND METHODS

2.1 Study Design

Engineering design and prototyping followed by a prospective, crossover, simulation-based study.

2.2 Device Development

- Needs Assessment: Interviews identified the need for compartmentalization, clear labeling, and organized layout.
- 3D Printing: Designed after detailed discussion with anesthesiologists and 3D printed
- Compartments: Spaces for airway tools (laryngoscope, ETTs, bougies) and labeled wells for drugs (adrenaline, vecuronium, midazolam, atropine, etc.).

2.3 Participants

- Fifteen anesthesiologists:9 male, 6 female
- Mean age: 35.4 years
- Mean experience: 8.7 years

2.4 Simulation Protocol

- Each anesthesiologist performed 2 runs with the standard setup and 2 runs with SADET (30 runs per setup).
- Environment: Simulated unassisted bedside intubation using Laerdal Airway Management Trainer and standardized kits.
- Metrics:
    - Setup time (ready to hands-on)
    - Intubation time (start to successful placement)
    - Drug/equipment retrieval time
    - Drug identification errors
    - User satisfaction (5-point scale)

2.5 Data Analysis

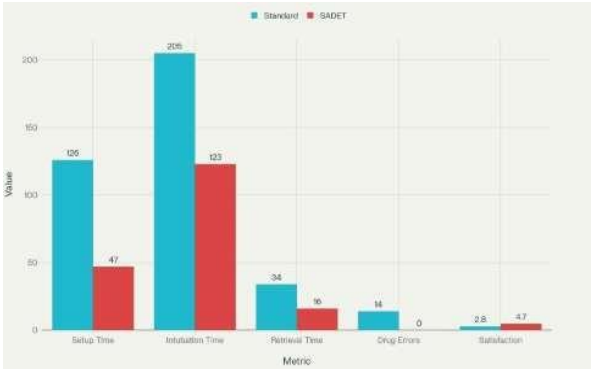
Paired t-tests for timing metrics, chi-square for error rates. Qualitative thematic analysis for feedback.

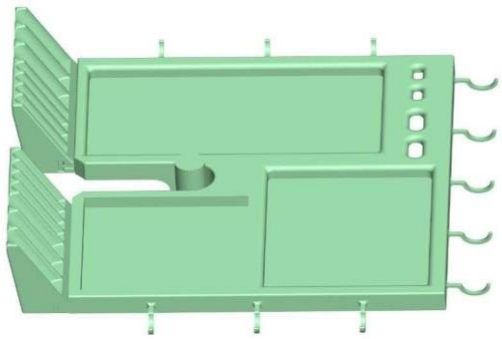
3. RESULTS

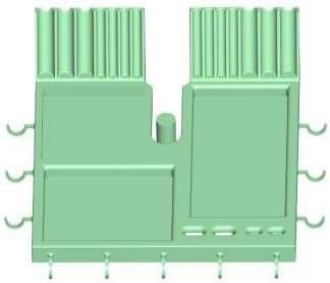
Statistical Analysis and Quantitative Outcomes

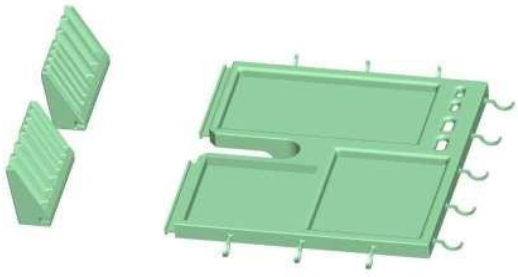
The following statistical methods were applied:

- Descriptive statistics (mean, standard deviation) were calculated for all continuous timing metrics including setup time, drug/equipment retrieval time, and time to successful intubation.
- Paired sample t-tests were employed to compare performance metrics between the standard setup and SADET within the same anesthesiologists, controlling for inter-participant variability.
- Chi-square test was used to compare categorical outcomes such as drug identification errors between the two setups.•


Standard
SADET
200
150
100
50
0
Value
126
47
205
123
34
16
14
0
2.8
4.7
Setup Time
Intubation Time
Retrieval Time
Drug Errors
Satisfaction
Metric







- In busy emergency rooms and trauma bays, where rapid airway control is lifesaving but assistance may be limited or delayed, SADET enables anesthesiologists to work methodically and swiftly without search delays or confusion.
- In prehospital environments such as ambulances or air ambulances, its lightweight, compact, and durable design facilitates quick deployment and organized airway management in confined spaces.
- In field hospitals, disaster zones, and military deployments—where staffing is often minimal and resources constrained—SADET's low-cost, reproducible 3D printed fabrication allows local production and customization to regional drug formularies.
- Rural or low-resource hospitals, which may face supply chain and staffing challenges, gain a reliable, sterilizable tool that reduces human error and improves procedural consistency.

Overall, SADET empowers anesthesiologists to perform unassisted intubations more confidently, safely, and efficiently. By streamlining the organization and accessibility of essential tools and medications, it reduces cognitive load, minimizes procedural errors, and shortens critical intervention times—factors all proven to improve patient outcomes in airway emergencies. Given its affordability, adaptability, and documented performance benefits, SADET stands as a practical innovation poised for widespread adoption in diverse clinical environments worldwide, especially where assistance is limited but the demand for expert airway management remains high. Future work will focus on clinical validation, material durability enhancement, and integration of smart features to further elevate its impact on airway management safety and effectiveness.

Strengths

- Cost-effective, local manufacturing
- Workflow-mapped layout
- High usability and user endorsement

Limitations

- Simulation-based (not clinical) study
- Field clinical trials needed

5. Conclusion

With this 15-anesthesiologist, 2-run per setup simulation, SADET reduced critical times and eliminated drug errors. Its affordable and adaptable design is well suited for resource-limited or high-pressure clinical settings.

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