10.5005/jp-journals-10035-1063

ORIGINAL ARTICLE

An Evidence-based Study on Traffic Flow in Operation Theater

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ABSTRACT

Introduction: An unusual amount of brisk and continuous traffic of people as well as goods crisscrossing every zone of the theater was noticed at an operation theater (OT) of a cardiothoracic center. Many storage areas were filled with cartons of various sizes which are good media for fungi and bacteria. Interactions with the theater staff and a study of the stores revealed that the traffic of people and goods was interconnected, and improper stores management was the root cause of the increased traffic. The focus of this study was to identify possible reasons for unusual traffic in the OT and to arrive at solutions in an objective manner for optimizing it.

Aim: The aim was to assess the traffic flow in an OT with the purpose to devise and implement measures for optimal and even flow of traffic during surgery and to create an additional operating room (OR) and instrument room and to improve the overall indoor air quality (IAQ).

Materials and methods: Scholarly articles regarding ventilation, traffic flow, and inventory management were reviewed along with information available onsite. The method of descriptive study was adopted. Data were collected after analyzing the traffic flow charts, prestudy questionnaire, nonstructured interview results, and nonparticipant observation study. Tools for the study included: (1) Anecdotal evidence, (2) checklists, and (3) rating scales of three different groups. Compliance levels of five different categories of people in the OT were assessed. Air efficiency microbial culture studies and wound swab cultures were carried out during and postimplementation.

Results: The process also resulted in generation of optimal traffic of staff and goods inside the ORs and decreased air turbulence, collateral benefits, such as (1) creating space for an additional OR, (2) creating a sterile area for storage of instrument packs, (3) optimal space management by segregation of bulk stores, (4) organized inventory control and indenting, and (5) good ventilation in ORs. Changes made in administration and training program increased awareness and compliance levels among staff. No surgical site infection was reported during poststudy observation period.

Conclusion: The study has resulted in improvisations originally conceived, planned, and implemented by the author at the work station. This study facilitated optimizing traffic of people and goods in OT and stores and in improving IAQ. Excellent cooperation among staff, clean and pleasant ambience, peaceful work situation, laid out standard operating procedures, segregated stores, and well-designed work hours boosted the morale of the entire staff.

Clinical significance: One of the main sources of airborne contamination in ORs is dead skin cells called "squames," each around 15 μm or less in diameter shed by staff and patients. A proportion of these may carry harmful bacteria. The rate of shedding increases with movement. This study focused on optimizing traffic of people and goods in the OT and thereby resulted in improving overall IAQ.

Keywords: 5S Methodology, Heating, ventilating, and air-conditioning, Indoor air quality, Operating room, Operation theater, Standard operating procedures, Storage, Surgical site infection, Traffic flow, Ventilation.

How to cite this article: Saraswati SV. An Evidence-based Study on Traffic Flow in Operation Theater. Int J Res Foundation Hosp Healthc Adm 2016;4(2):70-78.

Source of support: Nil

Conflict of interest: None

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INTRODUCTION

An unusual amount of brisk and continuous traffic of people as well as goods crisscrossing every zone of the theater was noticed at an operation theater (OT) of a cardiothoracic center. Many storage areas were filled with cartons of various sizes which are good media for fungi and bacteria. One of the sources of airborne contamination in OTs is the dead skin cells called "squames" shed by staff and patients.[1] The rate of shedding increases with movement (10^6 CFU/hour) as staff move briskly during surgery. A proportion of these will carry colonies of bacteria that grow on the skin (1 to 1,000 bacterial cells). Normal human skin is colonized with bacteria and different areas of the body have varied total aerobic bacterial counts.[2] Increased and avoidable traffic of people and goods can have harmful consequences to patients.[3,4] Figure 1 shows the layout of the OT where the increased traffic was noticed. The traffic flow of staff is shown in Figure 2. Though there are many other interlinked causes for airborne contamination in operating rooms (ORs), like aerosols, gases, dust, and lint,[3] it was observed that the main cause was increased and avoidable traffic of staff. It was felt that traffic could be regulated by proper planning and rearrangement of storage areas as shown in Figure 3. There were 12 storage areas filled with cartons of various sizes, which were good media for fungi and bacteria and these pollutants adversely affect indoor air quality (IAQ).[5] Interactions with the theater staff and

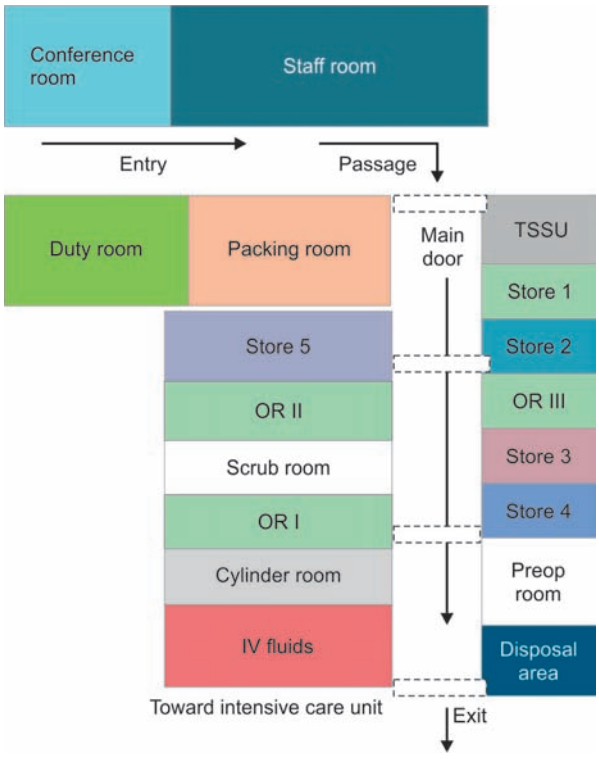


Fig. 1: Layout of OT

study of the stores and traffic flow chart of goods as shown in Figure 4 revealed that the traffic of people and goods was interconnected and improper stores management was at the root of the increased traffic of goods. Increased traffic inside ORs was due to poor material management, lack of awareness, and low compliance among staff. This resulted in the undermentioned issues that need to be addressed:

- Undue delay in procuring surgical and anesthesia items when needed
- Prolonged duration of surgery and increased working hours
- Deterioration of IAQ
- Unpreparedness for emergencies and lack of accountability
- Frequent postoperative wound infections especially in long drawn-out surgeries
- Low compliance among staff in theater management
- Compromised quality of patient care and safety
- Poor material management and decreased job satisfaction and morale among staff

OBJECTIVES

- To find out the root causes of increased traffic flow
- To collect data for analyzing the problem
- To interact with theater staff and obtain feedback
- To analyze data in light of the feedback
- To formulate solutions
- To implement measures to improve situation
- To review the end result after a reasonable time interval

MATERIALS AND METHODS

Material for the study required was all available at the site of study. Some material was sourced from the internet. Academic literature was reviewed to obtain an overview of ventilation systems. Observation of contents of stores in different storage areas, an assessment of space

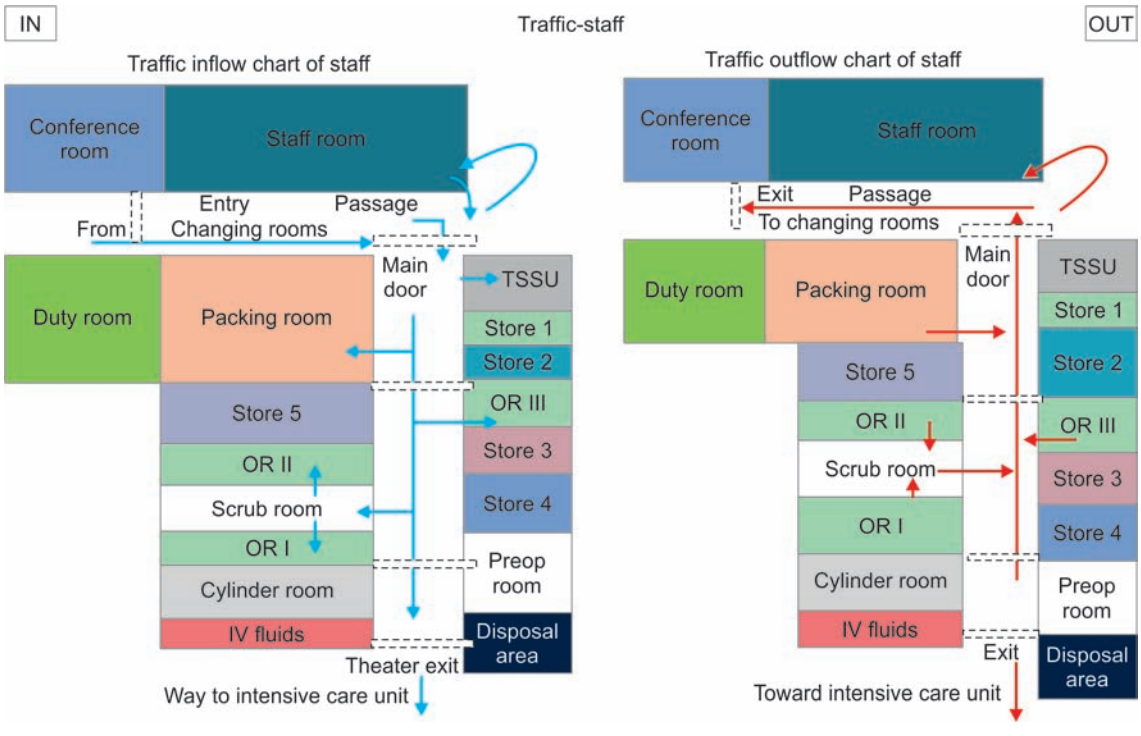


Fig. 2: Traffic inflow and outflow of staff

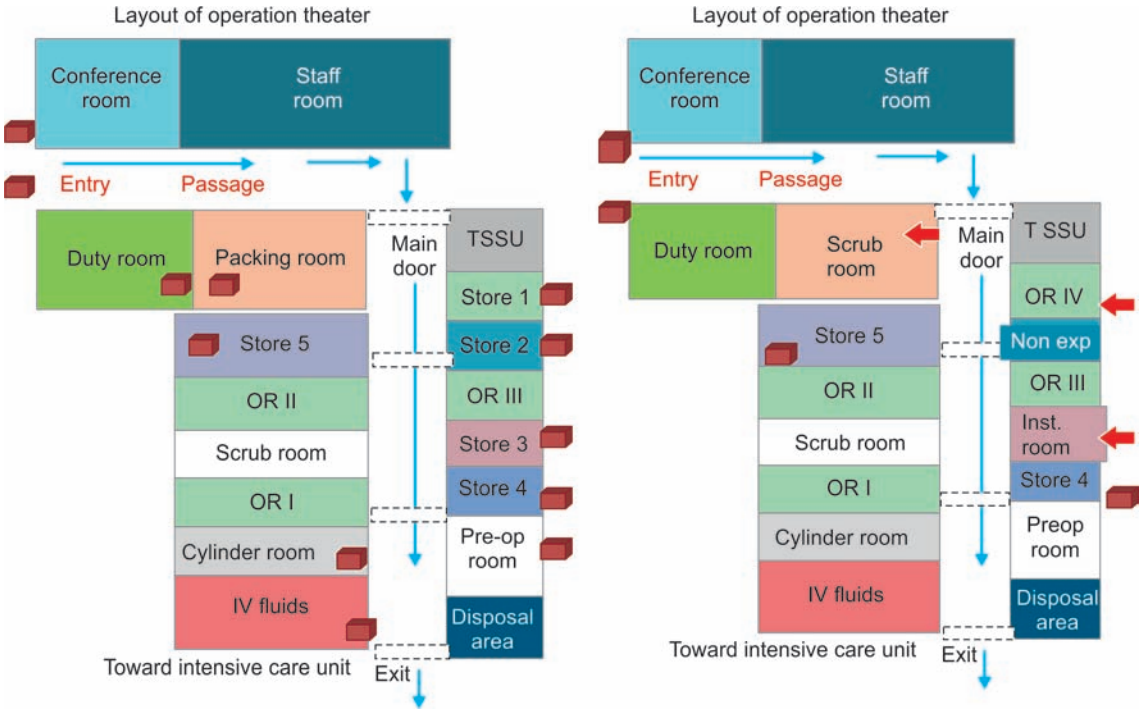


Fig. 3: Storage areas—before and after red arrows indicate

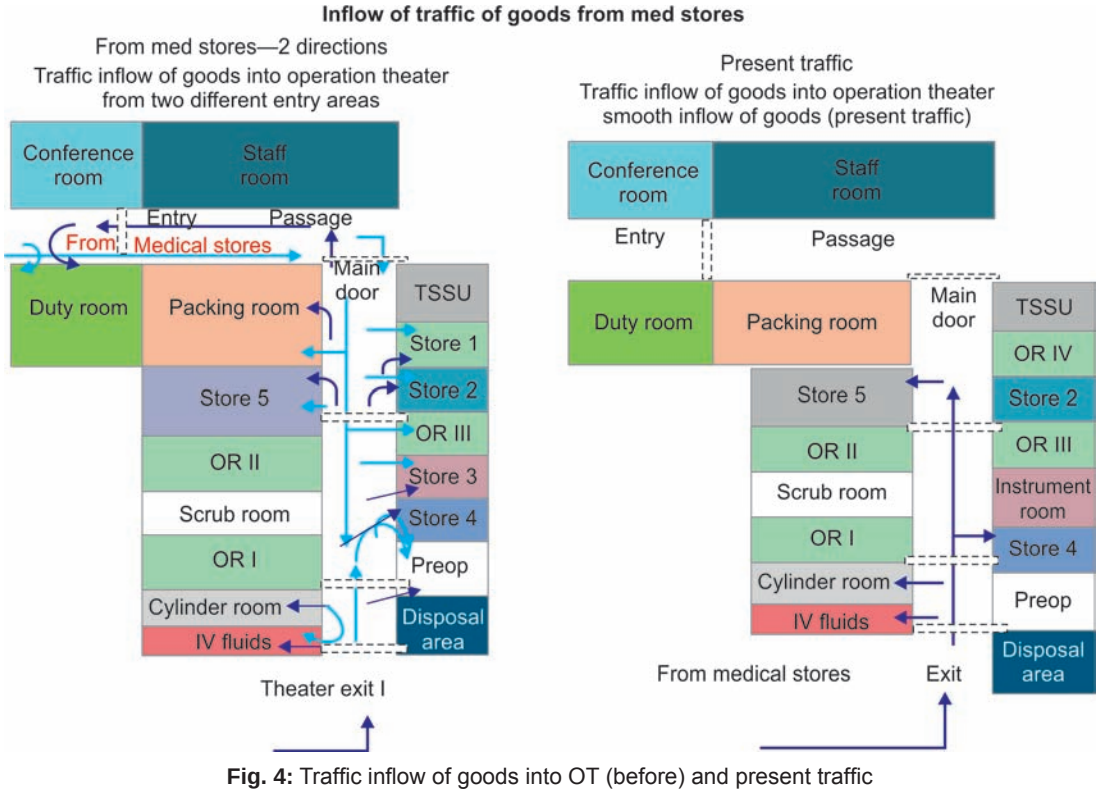
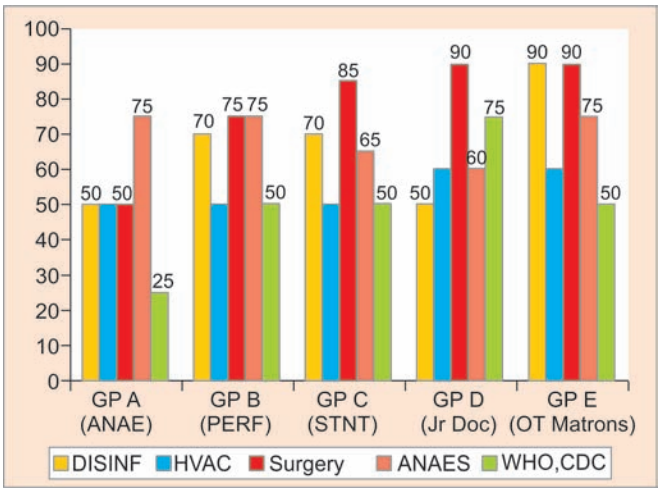
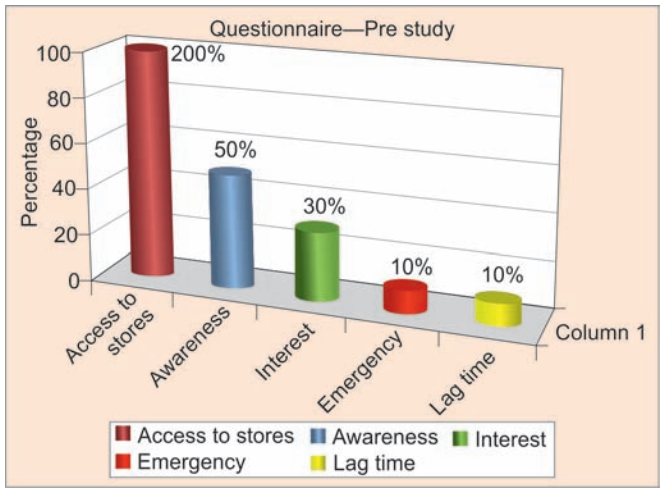


Fig. 4: Traffic inflow of goods into OT (before) and present traffic

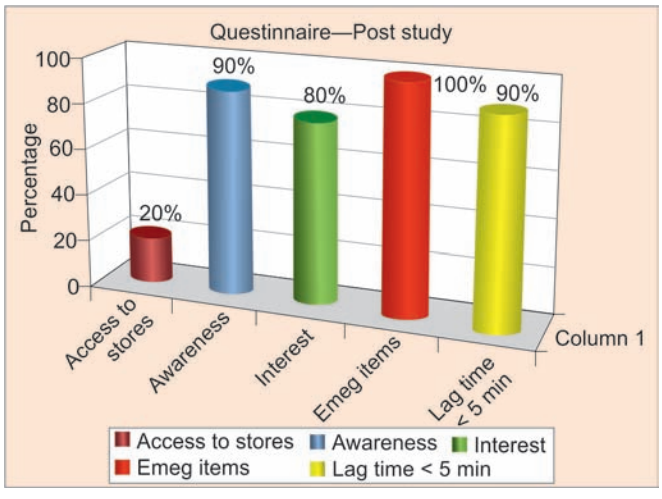
availability for shifting and segregation of storage areas, and ventilation checks to chalk out traffic flow charts were done. The method of descriptive study was adopted. Random unstructured interviews were conducted to assess compliance levels of five different categories of people in OT regarding disinfection; heating, ventilating, and air-conditioning; surgical techniques; and anesthesia techniques. Informal workshops were conducted to appraise staff of the World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) guidelines. Tools for the study used were rating scales of compliance in five different groups of professionals



Graph 1: Rating compliance levels among five groups of professionals



Graph 2: Knowledge levels regarding storage—prestudy



Graph 3: Knowledge levels regarding storage—poststudy

Table 1: Checklist scores of three categories of OR staff

		Checklist			
Sl. no.	*What to check*	*Score*	*GP I (Anaes)*	*GP II (Perf)*	*GP III (OT Matrons)*
1	All items and drugs were available	20	15	17	18
2	Emergency articles included	20	15	15	18
3	Additional material kept handy	20	10	10	15
4	Expenditure was correctly charted	20	18	18	18
5	Good time management (lag time > 1 hour)	20	15	15	17
	Total	100	73	75	86

Table 2: Observation of work pattern among three groups of OT staff

Anecdotal evidence (among OT Matrons, AORAs, pefusionists)					
Sl. no.	*Behavioral observation*	*Score*	*GP I (Anaes)*	*GP II (Perf)*	*GP III (OT Matrons)*
1	Location, cost, usage, availability	20	15	10	18
2	Preparation for next day	20	15	15	18
3	Replacing the used articles used	20	10	10	15
4	Performance	20	18	15	18
5	Extra effort to improve	20	10	15	15
	Total	100	68	65	84

as shown in Graph 1. All possible efforts were made to involve the staff at various levels to improve compliance. Knowledge levels of staff regarding storage pre- and post-study are presented in Graphs 2 and 3. Checklist scores of three categories of OR staff are presented in Table 1. Anecdotal evidence is tabulated and presented in Table 2 among three main groups: Anesthesia staff (group I), perfusionists (group II), and OT matrons (group III). Microbial culture studies to assess air efficiency and wound swab cultures of infected cases were carried out during and postimplementation as shown in Table 3. A master plan was made and implemented in 40 days to optimize traffic and reduce air turbulence (Graph 4).

PLAN AND IMPLEMENTATION

After a detailed study of the traffic flow charts, a plan was prepared. Traffic was to be restricted, modified, or stopped altogether to facilitate smooth functioning. To be stopped, traffic was marked and emptying of unnecessary storage areas was done as shown in Figure 3. To be restricted, traffic was decided and implemented. There were four different types of contents in stores

Table 3: Results of air culture after emptying stores

		Air culture reports			
Sl. no.	*Culture source*	*Report*	*Freq*	*Days of study*	*Remarks*
1	OR I,OR II	No growth after 72 hrs	Thrice a week	60	Sterile culture
2	OR III	Pseudomonas grown	Weekly	30	Growth ++
3	OR III	No growth after 72 hrs	Thrice a week	30	Sterile culture
4	OR IV and scrub room	No growth after 72 hrs	Daily	7 days	Done daily after emptying the bulk store
5	OR IV and scrub room	No growth after 72 hrs	Daily	2 weeks	Done daily after emptying the bulk store
6	Instrument room	No growth after 72 hrs	Daily	7 days	Done after emptying storage
7	Instrument room	No growth after 72 hrs	Thrice a week	2 weeks	Done after emptying storage

that needed segregation, i.e., items used in (1) surgery, (2) anesthesia, (3) perfusion, and (4) bulk storage. Entry into storage areas was restricted and traffic to be modified was decided. Traffic routes to decrease turbulence were opened as explained in Figure 4. Days were designated to collect supplies from medical stores. Entry for bulk stores and cartons in sterile areas was disallowed. There were no large containers to store items except cardboard boxes. Administrative authorities were approached for sanctions to purchase containers. Existing cartons were replaced with washable plastic containers. Checklists and standard operating procedures (SOPs) were made mandatory in ORs to know the stock of items available. 5S (Sort, Set, Shine, Standardize, Sustain) work place methodology was used to arrange stores. Segregation of stores resulted in control of traffic flow of goods. Clean and organized pre-operative environments reduce potential sources of injury and infection to care givers and patients.[4,5] Maintaining IAQ and temperature inside ORs is necessary to prevent OR infections and reduce contaminants.[4,6] Clogged air curtains were cleaned and damaged air handling unit (AHU) filters were replaced to improve IAQ. Changes were brought in biomedical waste management and staff was trained appropriately.[5]

LIMITATIONS

Implementation was completed in 40 days. As a precaution to prevent turbulence as well as postoperative infection, shifting was avoided when the cases were on. Initially, there was resistance to the idea in certain quarters. PowerPoint presentations and videos on hospital-acquired infection were screened to educate staff on air turbulence, air-conditioning, infection control, and biomedical waste management. Implementation was interrupted often due to shortage of staff. Since it was a rare kind of study, difficulties were encountered in collecting data from laboratory and the postoperative record section. Secondary sourcing and accessing published topics from books as well as websites on the issue was difficult.

RESULTS

The diagrammatic representation in Figure 1 is the layout of OT before implementation of study. It shows that there are a total of three ORs. The fourth OR was being used as store 1 and instrument room as store 3. Traffic flow path of staff into and out of ORs is explained in Figure 2. The number of storage areas was reduced from 12 to 4 as shown in Figure 3. This also facilitated creation of an additional OR (OR IV) with scrub, and in creating a sterile area for instrument packs as indicated by red arrows. The most important result of the study is generation of optimal traffic of people and goods inside the theater (Fig. 4). Every OR now has a checklist of items to make it self-sufficient. Results of checklists and anecdotal observations presented in Tables 1 and 2 clearly show that among groups I, II, and III, group III (OT nurses) had better preparedness and knowledge about cost and availability of stores and equipment. In Graph 1, compliance levels assessed in five groups of professionals showed better compliance levels in group IV (doctors) and group V (OT nurses). Certain changes made in administration and training programs, and introduction of SOPs and checklists helped in optimizing the traffic of staff. Graphs 2 and 3 present a comparative picture on five parameters: (1) The need to access stores, (2) awareness about storage and availability of stores, (3) involvement of staff, (4) management of emergencies, and (5) lag time for collection of stores. Staff followed "segregation of biomedical waste at source" and correct disposal methods. Good materials management lessened goods traffic in the ORs. The study resulted in optimal space management on account of segregation of bulk stores and labeling/color coding of items in issue stores. By involving and motivating the supporting technical staff and by drafting and implementing clear-cut SOPs, efficient functioning of AHUs was ensured. This resulted in good ventilation, optimum temperature, and humidity in ORs. A review of literature on ventilation was done. It was noted that this theater has "turbulent-mixed" type of ventilation, where fresh air is fed into rooms through ceiling outlets with integrated high-efficiency particulate

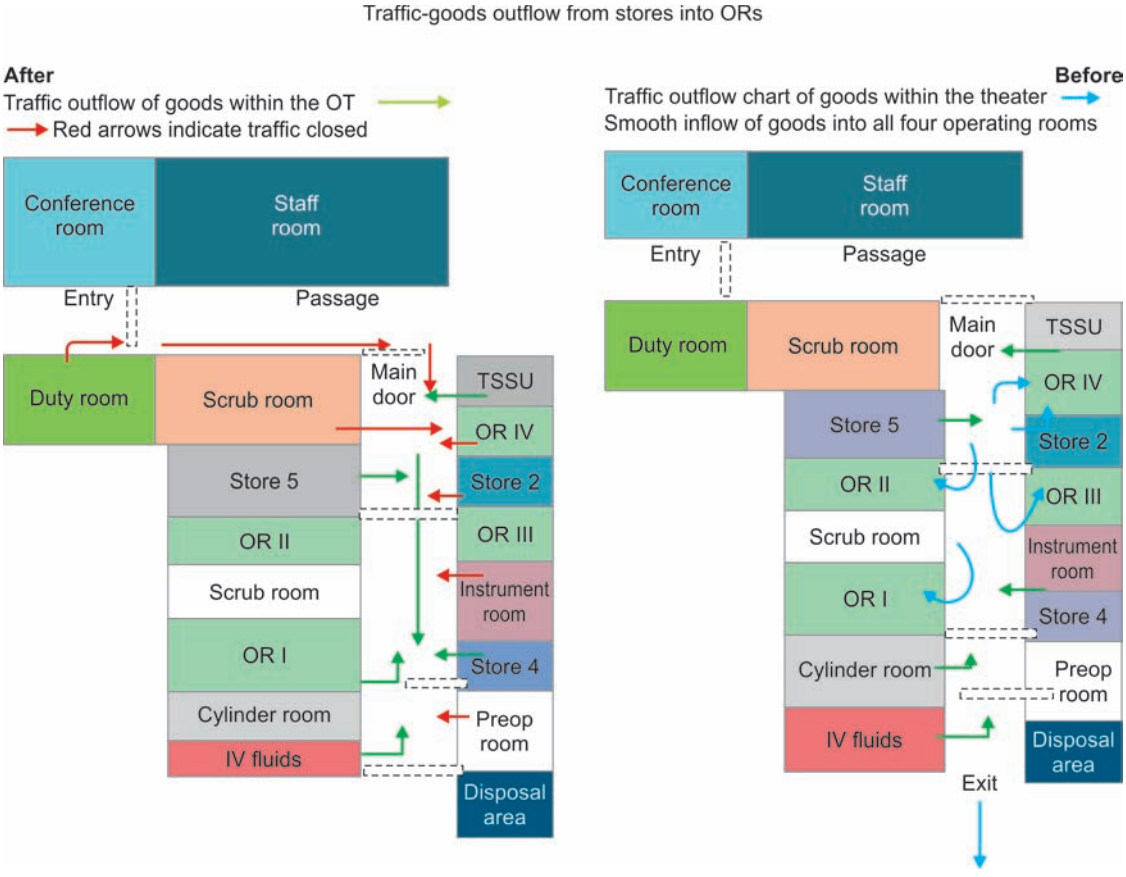


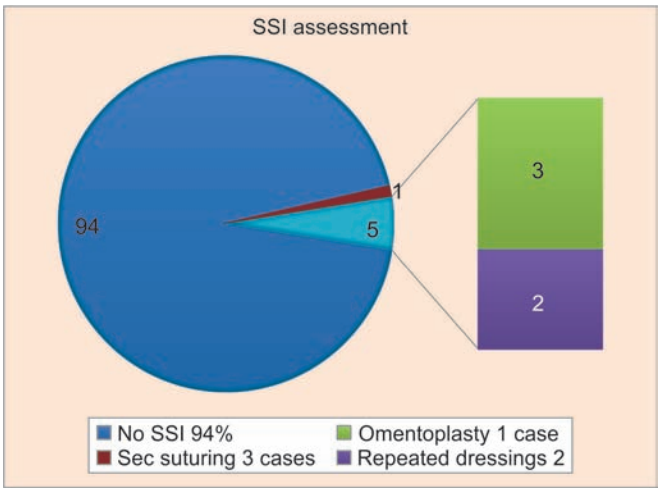
Fig. 5: Traffic flow of goods within the theater. Red arrows show closed traffic

air (HEPA) and mixed with room air. Settle plate method and blood agar cultures of air sampling were done during and after shifting and rearrangement of storage areas, and results were monitored as shown in Table 3. A total of 70 postoperative patients were observed during the 60 days of shifting and implementation of the project. Of these, six cases reported surgical site infection (SSI) as represented in Figure 5. No SSI was reported during poststudy observation period. The introduction of 5S methodology in inventory management resulted in better inventory control. Total computerization of indenting, procurement, and purchase procedures reduced the number of visits to hospital stores.

DISCUSSION

Major findings from this study and observations from literature review: Ventilation study was done by reviewing online research journals and articles available on manufacturing, engineering, and airflow studies apart from CDC and WHO guidelines.

- According to Thomas Schroth,[6] in his study he stated there are two types of ventilation. The ceiling area above the OT table is fitted with HEPA filters in air ducts where two different systems are employed. (1) Turbulent-mixed type of ventilation, where fresh air is fed into rooms through ceiling outlets with integrated HEPA and mixed with room air. (2) Low turbulence displacement flow where the OT table is continuously enveloped in veil of ultrapure air and shields it from surroundings (0.25–0.45 m/s). This theater had turbulent-mixed type of ventilation.
- Incidence of SSI is more in poorly ventilated areas. Incidence of SSI is also high when patient's surgical site is not properly prepared preoperatively.[7]
- In a study done by Leung and Chan,[8] nine hospitals revealed airborne contamination concerns. Effective dilution of air and removal of the contaminants by proper ventilation enhancement methods and ultraviolet germicidal irradiation was recommended.
- Melhado et al[3] in their study of "ventilatory systems in ORs" and Louise Belair and Leed,[9] in recommendations proposed for AIA Guidelines 2006 for design and construction of Hospital and Health care facilities in their publication dated 7/1/2006 "Reducing Operating Room Infections from Top Down," have both quoted a paper titled "Comparison of OR ventilation systems in the protection of surgical sites" (Memarzadeh and Manning, ASHRAE, 108, 2002), which suggests that the main factor of ventilation system design is control of the OR's central region, so the diffuser array should be large enough to cover main heat dissipating objects. The authors suggest ceiling-mounted equipment,



Graph 4: Results of wound swab culture done during study

monitors, lights, and unidirectional airflow along with diffusers with velocity of 25 to 35 fpm and return grills at 6″ above floor level. Measures were taken to keep the vent areas 6″ above ground level and clear of equipment. As this theater was under consideration for modernization, these aspects would be incorporated into future plans.

- Kabbin et al[10] in a review article on "Disinfection and Sterilization Techniques of OT" recommended removal of all foreign material from ORs and manual or mechanical cleaning of air-conditioning ducts on daily basis. Cleaning air curtains and air-conditioning ducts on a regular basis improves efficiency of filters.[10] Galvanized steel air curtains prevent warm air infiltration into cold areas and keep out flames and insects.
- Riley et al[11] in their article on "Indoor Air Quality and Infection Control" highlighted that pollutants in an OR include aerosols, fluids, and anesthesia gases. There are various types of ventilation systems with different airflow dynamics to address the issue of pollution, which need constant supervision. Poor discipline and not maintaining professional decorum can result in sloppy aseptic techniques.
- Nicholas[12] in his study of "Air Filtration Efficiencies in Hospitals" mentions three patient segregation categories where ventilation concerns apply. They are: (1) Airborne infection isolation room: Air may be recirculated if HEPA is used. Reversible air flow switching between protected environments and airborne infection isolation is not acceptable. (2) Protective environment room: Should have 99.9% HEPA efficiency. (3) Immune suppressed host in airborne infection isolation: Rooms with reversible airflow mechanisms or dual purpose are not acceptable. Some SSIs can be caused by particles which can be prevented with better airflow and proper filtration by following correct guidelines.
- Michalska and Szewieczak[13] in their study "The 5S Methodology as a TOOL" stated that implementation of 5S methodology of inventory management not only reduced the traffic of staff and goods but also resulted in organized inventory control and issue stores management. A study by Riley et al[11] explained that centralized receiving, storage, and trash removal, both temporary and permanent are issues that become more complex in hospital settings. With disruptions to ongoing activities during construction, renovation, shifting stores, etc., minimizing inconvenience to patients should be one of the important aspects to be kept in mind. Accordingly, material path ways, barriers, and training of workers need to be done. The 5S methodology improved efficiency and services. It also resulted in reduction of inventory and supply costs and recapturing of valuable spaces and in minimizing overhead costs. These benefits were sustained post-study. The 5S system reduces waste and optimizes productivity through maintaining an orderly workplace.
- Al-Saffar Ali,[14] Royal College of Surgeons of Ireland, in his review study, explained that the application simplifies the activities through reduction of unproductive/unnecessary activities.
- Manual for implementation of 5S in hospital setting[15] mentions that inventory systems of various items need proper tagging, labeling, and periodical review for improvement. It is important that all workers and staff involved should understand the benefits of the 5S methodology and follow rules. It should be reviewed once every month which helps its sustainability. Implementing 5S methodology in a group of disciplined workers leads to improvement of human relations.
- An additional OR with a scrub room was now available reducing the waiting period for surgery. All sterile packs now remained in sterile zone as a new instrument room in the sterile area was made available by rearrangement of stores. The new OR IV and the instrument room are connected to AHU and the air pressure in the OR IV is less in comparison to other ORs and instrument room. Hence, OR IV is more suitable for noncardiac surgeries and hence, utilized for the same.
- Changes in theatre sterile supply unit were made. Instruments were segregated into various packs. Disposable sterilization wraps and biological indicators and integrators for sterility efficiency tests were introduced.
- Maximum traffic was caused by junior staff. The number of airborne microorganisms in ORs is largely proportional to human activity. The more the number of people in ORs, the more contamination, as they

constantly close and open doors causing the air in ORs to mix with corridor air. Traffic in ORs when surgery is on should be minimal, which can be achieved by making every OR self-sufficient. Hence, staff rotation plans were implemented and staff detailed by rotation to ORs, TSSU, and other duties.

- In the area of waste management people needed stricter measures and repeated reminders. More BMW buckets were procured for this purpose. Staff were motivated and trained to follow the guidelines set up for waste management.

ISSUES ADDRESSED

- The lag time in procuring surgical and anesthesia items was effectively reduced as the ORs were made self-sufficient by introduction of tally cards and checklists.
- Involvement and awareness among OT staff has improved as shown in Graph 3.
- Indoor air quality was better postimplementation of study. Removal of excessive bulk storage, cleaning of air curtains, and periodical maintenance of AHUs helped in achieving better IAQ.
- There was accountability and readiness for all emergencies in all ORs. As reflected in Graph 3, compliance of staff in matters of inventory management has increased with continuing education.
- Seventy cases were observed during and post study for SSI. Six cases reported SSI, out of which one underwent omentoplasty. The rest five patients were subjected to repeated dressings followed by secondary suturing in three cases. There was no incidence of SSI in the poststudy observation period.
- Quality of patient care and safety improved as staff had more time to interact with patients. They were even spotted jotting down notes and clarifying queries and counter checking items using tally cards.
- There is organized inventory control and excellent material management.
- Certain items like microwave, water filter, footwear were procured. Better ambience and comfortable work atmosphere was created.

OBJECTIVES ACHIEVED

- The root cause of increased traffic flow was interlinked with goods and stores.
- Data for analyzing the problem were collected at the site.
- Interaction with theater staff yielded useful feedback.
- Data were analyzed and solutions were formulated to address the issues.
- A master plan was conceived and implemented with practical measures, keeping in view the ongoing cases of surgery.
- End results were reviewed continuously for 60 days and also after a reasonable time interval.

CONCLUSION

Not only was this study challenging due to its rare theme but also very interesting in terms of gaining knowledge. Interesting points that have come to notice:

- Cluttered and badly managed stores can cause traffic disturbances.
- Increased traffic in ORs interrupts the sterile air flow within the ORs.
- Indoor air quality reduces when there is more traffic.
- Badly arranged stores can have psychological impact on staff.
- Cluttered stores which harbor bacteria can predispose to postoperative infections.
- The nature of IAQ in the theater can alter the statistics of good postoperative results, and can increase morbidity and mortality.
- Traffic in the theater and within the ORs should have a definite purpose and a clear route to follow. The number of viable airborne microorganisms for a given amount of OR ventilation is largely proportional to human activity.
- A total of 50% of the staff working in theater have very little or no knowledge about air quality, various gadgets of air-conditioning, store management, turbulence, so they should be frequently updated regarding these aspects.
- Waste management is not one person's job but a teamwork.
- High cost of SSI can be easily brought down by improving IAQ.
- It is difficult to change an existing system but it is accepted when reasons are given and results shown.
- Clearly laid down standing operative procedures are not only useful in understanding a procedure but also needed to set in a routine.
- Cooperation between staff and the administrative authorities yields good results.
- No work is kept pending when equipment, ledgers, and stores are kept in order.
- Effective and significant achievement of this study is promotion of a harmonious working relationship among the staff and better patient care.
- The golden adage "a place for everything and everything in its place" is most applicable in theater and stores management.

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