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RESEARCH ARTICLE

Operating room environmental improvements with Venturi valves and Environmental Quality Indicator risk prediction may help reduce Surgical Site Infections

***Jennifer A. Wagner, Ph.D.**
Managing Partner, OnSite-LLC
2274 Tamarisk Court
Discovery Bay, CA 94505
925-727-2703
jwagner@onsite-llc.com

Greeley Damon G. PE, CEM, HFDP, CBCP, EDAC, CHFM
Managing Partner, OnSite-LLC
6825 Bayview Club Dr., STE 1A
Indianapolis, IN 4625

Sieber Marnie S. MSN, RN
Infection Preventionist
Indiana University Health

ABSTRACT:
Introduction: There is mounting evidence supporting the connection of the operating room airborne environment to Surgical Site Infections (SSI). Environmental Quality Indicators (EQI) can be measured to determine the risk of microbial contamination in the OR by room sector. This risk picture is used to inform educated improvements to the aseptic environment. When improvements based on the EQI risk picture are combined with precise control of the airborne environment using Venturi technology, the asepsis of the OR is maintained and the risk of contamination is lower. This study sought to determine if precisely maintained asepsis in the OR based on EQI risk picture lowered the SSI rate.
Methods: The environmental quality indicators in a Craniotomy OR were measured and a risk picture, by room sector, was created. The EQIs measured included air change rates, humidity, temperature, pressure, particle counts, occupancy, traffic patterns, air flow and directionality, and door openings, among others. Improvements to the OR performance were made based on the risk picture and Venturi technology was used to precisely control the airborne environment. SSIs were tracked for 17 months prior to improvements and then for 10 months following the improvements.
Results: The asepsis of the OR airborne environment was improved and an EQI risk picture was developed following improvements to document improvement. In the 17 months prior to improvements to the OR, there were 14 SSIs out of 430 total surgeries and the SSI rate was 3.9%. In the 10 months following the improvements, there was 1 SSI out of 180 surgeries, and the SSI rate was 0.5%. The reduction in SSIs was statistically significant at p=.0377 following improvements.
Conclusion: Improvement of the airborne environment in ORs improves the asepsis and may help reduce SSI.

Keywords: Surgical Site Infection, Environment, Environmental Quality Indicators, Risk Assessment

Introduction:

Surgical site infections (SSI) occur when bacteria, often normal human flora, access the open surgical wound and proliferate. These bacteria are opportunistic pathogens and under the right conditions can result in infection, especially in higher risk patients. They can enter the wound on contaminated surgical instruments, implantable items or doctor's hands, or they can be carried through the air on shed skin cells or other particles and be deposited into the wound or onto items that contact the wound.[1,2,3] Identifying the risk for microbial contamination in operating rooms (OR) informs corrective actions and optimization of the aseptic environment to reduce SSI. Corrective actions include maintenance of air change rates, air flow quantity and directionality, maintenance of pressure, humidity and temperature, among many others. The use of Venturi valves has been shown to be an effective way to maintain and control air flow and room pressure in environments that are inconsistent and unpredictable, such as an intensive care unit[4], laboratory or operating rooms. Venturi valves are known for their accuracy and speed with which they adjust to changes in the environment to maintain desired pressures and directional air flow.[5]

In this retrospective study, an operating room at Indiana University Health (IUH), used primarily for Craniotomy procedures was experiencing, what they considered to be, elevated levels of SSIs. Infection prevention had implemented typical clinical bundle including ERAS, smoking cessation, chlorhexidine bathing as well as the use of a topical vancomycin power. The clinical interventions alone did not significantly reduce SSIs, p=.718, over the course of 17 months. Therefore, IUH infection prevention staff elected to study the environment to better understand areas of risk and identify strategies to improve the asepsis of the operating room. The objective of this retrospective, comparative study was to determine if modifications to the operating room environment, intended to improve asepsis, statistically significantly improved the infection rate. The results of this study are important for the infection prevention team when recommending the inclusion of environmental improvements in clinical bundles aimed to reduce surgical site infections.

Methods:

The Environmental Quality Indicators (EQI), (including temperature, humidity, air flow velocity and direction, air changes per hour, door openings, particle counts, CO2 levels (occupancy) and traffic, room layout and equipment placement) were evaluated and the risk of contamination was determined by sector within the OR (Figure 1A and 1B).[6] The risk for potential contamination within each sector of the room was determined by the number of EQI parameters that were out of range (example: humidity too high, excessive door openings, increased particle counts). The higher the EQI number, the greater risk for environmental contamination. The EQIs assessed, included air flow and directionality, room pressurization and air change rates, humidity, temperature, and the overall use of the room which included occupancy, door openings and traffic patterns. Based on these EQIs and the risk picture, the Venturi valves were engaged to improve the pressure and air flow within the OR. Venturi air valve technology, based on the Venturi effect, reduces the air pressure that results when air flows through a constricted area of the duct, thereby maintaining a more consistent and controlled flow of air. With precise and consistent maintenance of the pressurization and air flow, a post modification EQI risk picture was developed (Figure 1B).

Figure 1A - Before **Figure 1B - After**

Figure 1: depicts the operating room Environmental Quality Indicator (EQI) risk pictures. Figure 1A is the risk picture before modifications were made to the room and Figure 1B is the risk picture after the room was optimized for the best use of the sterile field. The OR is divided in to sixteen equal sectors with the four sectors in the center constituting the sterile field. The blue line demarcates the sterile field. Each sector is color coded to represent relative risk of contamination. Red – high risk; Yellow – moderate risk; Green – low risk; Blue – ultra low risk.

In Figure 1A, the EQI risk picture of the OR before engagement of the Venturi valve to control pressurization and air flow is shown. The four sectors in the center (blue square) represent the sterile field and this risk picture demonstrates how the sterile field is shifted toward the top and is primarily within the high (red) to moderate (yellow) risk level. Figure 1B depicts the EQI risk picture of the same OR after improvements to precisely control pressure and air flow were made. The four sectors in the center, representing the sterile field (blue square), demonstrate that the air flow is protecting the sterile field with primarily low (green) and ultra-low (blue) risk of contamination.

Results:

After improvements to the OR were made, the EQIs were continuously monitored, and pressure and air flow were consistently maintained. SSIs continued to be tracked and were compared to the 17 months prior to adjustment of the environment. Fourteen Craniotomy SSIs occurred between January 2017 and May 11, 2019, a total of 17 months and a total of 430 surgeries (14 SSI/430 surgeries), which is 3.9%. Following implementation of the risk-based improvements, after these initial 17 months, there was 1 Craniotomy SSI in the next 10 months, from May 12, 2019 to March 2020 and a total of 180 surgeries (1 SSI/180 surgeries), which is 0.5%. The decrease in SSIs following alterations to the OR was statistically significant at $p=.0377$. The Chi Square analysis comparing just the ten months prior to the change date, July 2018 to May 11, 2019 (6 SSI/154 surgeries before), which is 3.2%, to the ten months following implementation, May 12, 2019 to March 2020 (data above) was also significant at $p=.033$ (Figure 2). Due to the novel coronavirus' increased demands on HCWs as well as staffing shortages, we have been unable to obtain data past March 2020.

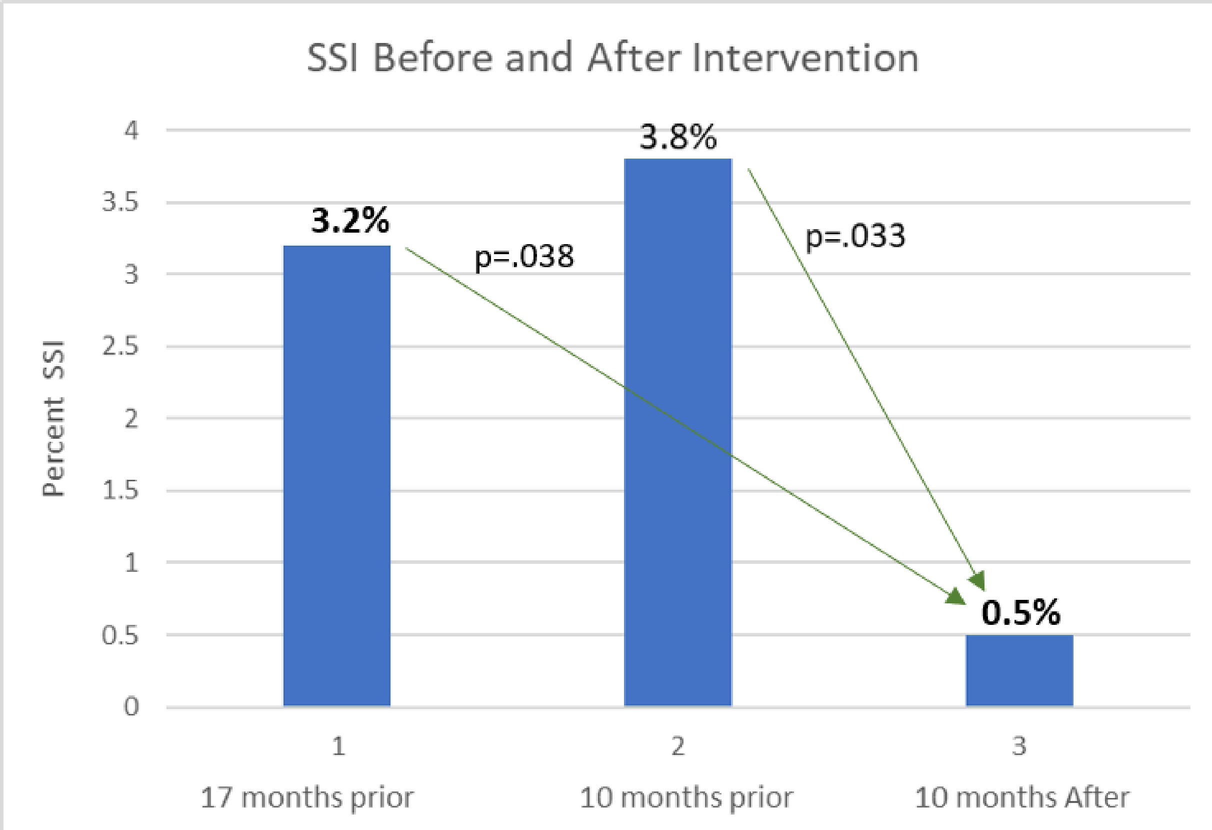

Figure 2: depicts the statistically significant SSI reduction following EQI improvements with Venturi precision and control of pressure and air flow.

Discussion:

There is evidence that the airborne environment in an OR plays a role in the promotion of asepsis and associated reduction in SSI.[6] The people in the OR, doctors, nurses, scrub techs, sales reps, all shed bacteria carrying squames into the environment.[7] These particles settle out of the air and can land on surgical instruments, the surgeon's hand or in the wound[1-3] creating potential for surgical site infections to occur. There are many techniques employed in ORs to reduce the risk of SSI, including air distribution systems, prophylactic antibiotic administration, gowning and gloving procedures, hand washing, wound irrigation, instrument sterilization and many others. The fact that these techniques are universally accepted, and some are regulated or enforced by The Joint Commission, AORN, APIC and others, is an indication that the importance of maintaining an aseptic environment in the OR is essential to reducing SSI. However, as described in the introduction, these measures may not be enough to eliminate SSI and additional attention to the environment in the OR may be required.

Additionally, there are prescriptive design considerations, such as those recommended by ASHRAE.[8] These recommendations include unidirectional supply air delivery over the sterile field, the use of low wall air returns to ensure the air exits the room, positive pressurization, maintenance of air exchange rates, humidity levels and temperature among others. However, even when these prescriptive benchmarks are met, the performance of the room may not be optimal and an unrecognized potential for contamination may exist. A common example is the placement of a supply cart up against one of the low wall air returns, essentially blocking the return so that the air supplied to the room cannot exit the room with a direct path, creating turbulence which in turn can entrain contaminants and degrade the asepsis of the OR. Other common circumstances that result in sub-optimal OR performance include unbalanced or non-functional supply diffusers, which result in the filtered supply air failing to reach the height of the patient bed resulting in areas of turbulence and higher risk of contamination.

The EQI risk picture method of evaluating the performance of the operating room by sector allows for these anomalies to be detected and remedied resulting in a better performing OR with reduced risk of contamination in critical zones.

Continually or periodically monitoring the OR EQIs helps to maintain an aseptic environment.

Furthermore, technology exists to help control the environment. Technologies include state of the art air supply and EQI monitoring as well as precise control of the environment. As described in the introduction, the Venturi technology of environmental control is extremely precise ensuring that the OR continually maintains optimal performance and hence a lower risk of contamination. In this study, the EQI risk picture combined with the Venturi technology helped to further reduce SSIs by first assessing the performance of the OR, followed by optimizing the performance for reduced risk and enhanced asepsis, and lastly by precisely controlling the optimized environment to ensure it remained optimal.

Conclusion:

The EQI risk picture identified the areas of higher risk within the operating room allowing for informed optimization, including instrument and equipment placement, conscious avoidance of high risk areas, and ensuring balanced air supply and effective air return. These environmental improvements as well as the use of the Venturi valve to consistently maintain proper pressure and air flow, occurred prior to and could be associated with the observed reduction in surgical site infections in this study. In conclusion, when the effort to reduce SSIs using clinical interventions alone does not produce the desired reduction, the OR airborne environment should be considered and evaluated. Additionally, more studies aimed to determine the connection between airborne OR environments, increased risk of contamination and surgical site infections are warranted.

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Indiana University Health, OnSite-LLC and Phoenix Controls worked together to improve the airborne environmental quality within the operating room. IUH implemented the suggestions of OnSite, based on the EQI risk prediction and as a part of the intervention, Venturi valves were engaged to help promote and maintain a cleaner, more controlled environment.

Limitations:

The study was limited to one OR chosen by the infection prevention team because the infection rate was high and clinical interventions did not yield the desired improvements. Infection data was only able to be obtained for ten months following the improvements due to the Coronavirus pandemic's toll on healthcare. The seventeen months prior to the improvements averaged 25 surgeries a month and the ten months following the improvements averaged 18 surgeries per month.

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