Effectiveness of Scientific Air Management S400 units in the reduction of various size airborne particulates in the health care environment.

Dr. Gary Russotti & Dr. Jay Nisberg

Abstract

Although ventilation systems in hospitals are designed to remove particulates through use of high efficiency particle air (HEPA) filters and kill pathogens with ultraviolet light (UV), viable pathogens can still be detected in the air of health care facilities. Particles containing dust and other microscopic debris can remain suspended in air for long periods of time, with the smallest particles remaining airborne longest. Pathogens often attach themselves to airborne particles that can become a food source and offer transportation. These pathogen particles can travel long distances and infect others upon inhalation or ingestion.

A portable air disinfection device that incorporates the use of both HEPA and UV was used to supplement a hospital's ventilation system in various areas of the facility. An independent air sampling company was contracted to access how well the device reduced air particles. Particle sizes ranging between 0.3-10.0µm were included in the evaluation. Before placement of the air disinfection device, baseline air sampling was conducted. Additional air samples were then taken after either 30-minutes or 1-hour of air disinfection device use, depending on the location. Multiple air samples were taken, and averages recorded. Before and after air samples were compared for five different particle sizes between 0.3-10.0µm. There was a statistically significant reduction in all particle sizes using the air disinfection device. There was also a strong correlation in the ability of the air disinfection device to reduce overall particulate counts using the Pearson Coefficient Correlation test, which returned an r-value of 0.971.

Authors

Gary Russotti MD, MS, FACS; Jay Nisberg, PhD

Objective

The purpose of this study was to evaluate the effectiveness of Scientific Air Management S400 units in the reduction of various size airborne particulates in the health care environment.

Background

Airborne particles are a vehicle for viable pathogenic bacteria, fungal and viral transport and can diversify the microbiome long distances from the loading site.[1-3] Bacteria is capable of developing up to 104 colony forming units (CFU) on a particle, with particle size having been linked to the type of bacteria carried.[1,2] Air pollution boosts microbial diversity and therefore increases the opportunity for the presence of breathable pathogenic microorganisms.[1,4] Basic human activities such as breathing and talking can add to this air contamination. Therefore, the more human beings in an area, the greater the risk for airborne pathogen transmission.

Healthcare facilities are places where large numbers of sick or immune compromised individuals seek treatment. Patients waiting to be seen or undergoing care are at risk of developing further illness from others.[5-7] A sick person breathing contaminated air risks additional or prolonged illness from the environmental microbiome.[4,8] Patients that remain in the built hospital environment for extended periods of time are most at risk for developing nosocomial infections.[6,8]

The Wells-Riley model was used in a 2018 study (Cheong & Lee, 2018) to better understand the risk of airborne pathogen transmission to patients in adjacent health care spaces. The study confirmed that pathogens are capable of infecting other patients throughout a ward to varying degrees.[9] An interesting finding was that pathogen transmission was sometimes highest in patients farthest away from the contaminated source patient.[9]

Pseudomonas, Bacillus, Staphylococcus and Micrococcus are some of the more common pathogens that have been isolated from airborne particles.[2,7,8] Airborne transmission of Staphylococcus has also been associated with advanced bacterial colonies known to form biofilms on surfaces.[10] Difficult to treat bacterial infections that can be transmitted by means of air currents include bacteria such as pneumonia, gonorrhea and salmonellosis.[10] Equally concerning has been the development of airborne multidrug-resistant Mycobacterium tuberculosis (TB) in otherwise healthy individuals.[5,11,12]

Even with a well-maintained hospital ventilation system that has HEPA, the air in health care can still be a mechanism for pathogen transfer.[4] A 2019 study conducted in a hospital Neonatal Intensive Care Unit (NICU) identified high counts of Staphylococcus with other multi-drug resistant organisms (MDRO) associated with 2-7µm particle sizes.[10,13] This study (Morgado-Gamero et al., 2019) found that smaller particulate sizes weigh less and can remain suspended in air for shorter periods of time, allowing bacteria and other pathogens to attach themselves. This study concluded the most concerning particle size was in the 0.6-2.1µm range and most effectively addressed using an air purification device that incorporated UV irradiation in its design.[10]

Bacteria is not the only airborne pathogen that places patients at risk. Less than one colony of pathogenic fungi such as Aspergillus can be detrimental to immune compromised individuals.[5,14] The degree to which patients are able to fight fungal infections depends on the amount of fungal spores inhaled and ability of the individual to fight the fungal infection.[15] Aspergillus spores can vary in size and HEPA filters may not always capture pathogenic spores.[7,13] Therefore, devices that use both HEPA and UV are more capable of addressing airborne fungi.[5,16]

This study aimed to understand if there is a correlation between use of S400 units and the reduction of airborne particle counts in several different hospital areas. Evaluation of both patient and non-patient spaces was used to create a holistic picture of SAM's air particle reducing capabilities.

Methodology

A 728-bed magnet nursing certified hospital in South Florida was selected as the test site. Approval was received from the hospital to allow a third-party testing agency to conduct and report air sampling results to both hospital leadership and S400. Test results were compiled and placed into an *Environmental Sampling* report for confidential distribution.

Ten locations that included both patient and non-patient areas were identified. The second-floor fitness center and physical therapy room were selected in the Medical Arts Building. The first floor waiting room, emergency department, operating room nurses' station and operating room hallway were selected in the main hospital. Cardiac-pulmonary administrative offices, a cardiac-pulmonary services room and an acute multi-specialty care room were selected on the second floor of the main hospital. A detached soiled laundry area was also included in the evaluation.

Baseline air sampling occurred in all rooms prior to placement of S400 devices. Two S400 units were placed in the fitness center, while only one S400 unit was placed in the physical therapy room. S400 was run for 1-hour in the fitness center and physical therapy room before measurements were taken. Three S400 units were placed in the emergency department and run for 30-minutes before measurements were taken. Two S400 units were placed in the acute multi-specialty room and run for 30-minutes before measurements were taken. One S400 unit was placed in each of the following: waiting room, operating room nurses' station, operating room hallway, cardiac-pulmonary administrative offices, cardiac-pulmonary services room and detached soiled laundry and run for 30-minutes before measurements were taken. Measurements were taken during normal business operations between 8am-5pm with typical occupancy for a Thursday.

All rooms had four walls and doors that opened and closed immediately after allowing entry or exit during S400 operation except for the first floor waiting room and emergency department. These two areas had operable doors that opened and remained opened for an extended period of time to allow proper egress passage.

Air sampling was performed by an independent contractor with no affiliation to S400. Direct reading measurements for respirable particle concentrations in the 0.3µm, 0.5µm, 1.0µm, 2.0µm, 5.0µm and 10µm particles were accessed using a Fluke 983 and Met-One GT-526S. The particle counters were purged and zeroed between each location using a Sterapore zero counter filer. The sample volumes were set in concentration mode to capture a 60 second sample at $1/10^{th}$ $foot^3$/2.83L of air. Multiple baseline and multiple final measurements were collected in their respective areas and totals were averaged.

Results

S400 achieved an overall 34.6% reduction in air particle counts in the fitness center. The greatest reduction was identified in the 10µm particle size, achieving a 100% reduction. The second greatest reduction was identified in the 2µm particle size with a 42.0% reduction. The third largest reduction was identified in the 5µm particle size achieving a 37.5% reduction with the 0.3µm size achieving nearly the same reduction at 37.4%. (Graph 1, Figure 1)

Graph 1 (Fitness Center)

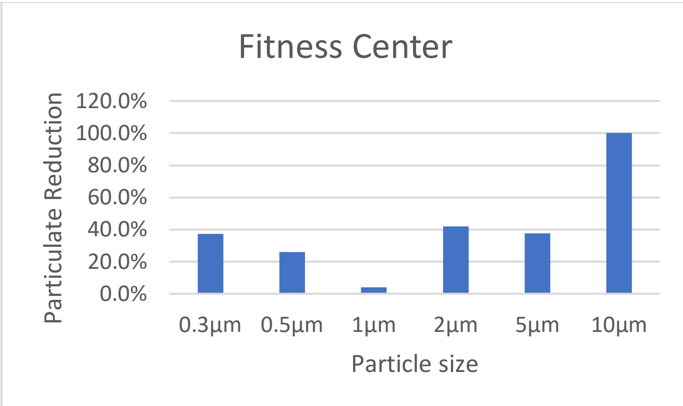

Figure 1 (Fitness Center)

	Fitness Center		
Particle Size	Before	After	Reduction
0.3	4650	2909	37.4%
0.5	862	637	26.1%
1.0	204	196	3.9%
2.0	50	29	42.0%
5.0	8	5	37.5%
10	1	0	100.0%

The physical therapy room also achieved the highest particulate reduction in the 10µm particle size, achieving 100% as well. The second highest particle reduction in the physical therapy room was seen in the 0.3µm size at 55.2%. The third highest reduction was observed in the 0.5µm particle size, achieving a 52.7% overall reduction in particle counts. (Graph 2, Figure 1)

Graph 2 (Physical Therapy)

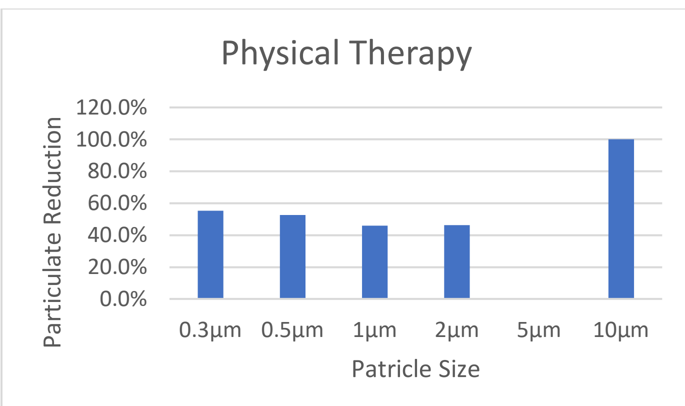

Figure 1 (Physical Therapy)

	Physical Theray		
Particle Size	Before	After	Reduction
0.3	5190	2324	55.2%
0.5	1002	474	52.7%
1.0	263	142	46.0%
2.0	78	42	46.2%
5.0	4	4	0.0%
10	1	0	100.0%

The first floor waiting room also saw a 100% reduction in the 10µm particle size, with the second highest particle reduction seen in the 5µm particle size (50%). The third highest reduction was seen in the 2µm particle size at 49.8%. Overall particulate count reduction in the waiting room was 36%. (Graph 3, Figure 3)

Graph 3 (Waiting Rooms)

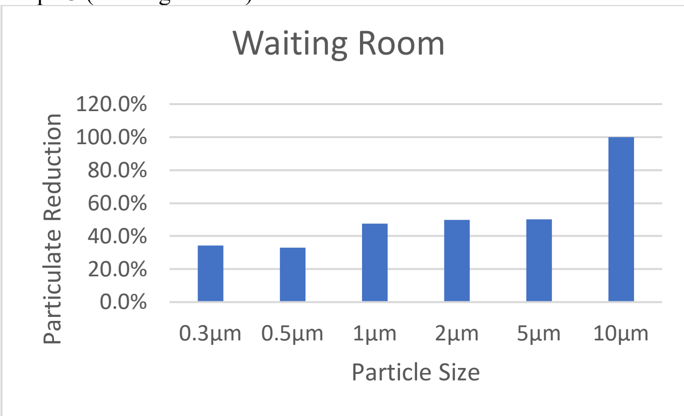

Figure 3 (Waiting Rooms)

	Waiting Room		
Particle Size	Before	After	Reduction
0.3	4066	2666	34.4%
0.5	834	560	32.9%
1.0	434	228	47.5%
2.0	293	147	49.8%
5.0	12	6	50.0%
10	1	0	100.0%

Consistent with previous results, the greatest particle reduction in the emergency department was seen in the 10µm particle size, achieving a 100% reduction. The second greatest particle reduction was in the 2µm size at 75.2%. The third highest particle reduction was found in the 0.5µm size at 69.9%. The emergency department received an overall 59.1% reduction in particle counts. (Graph 4, Figure 4)

Graph 4 (Emergency Department)

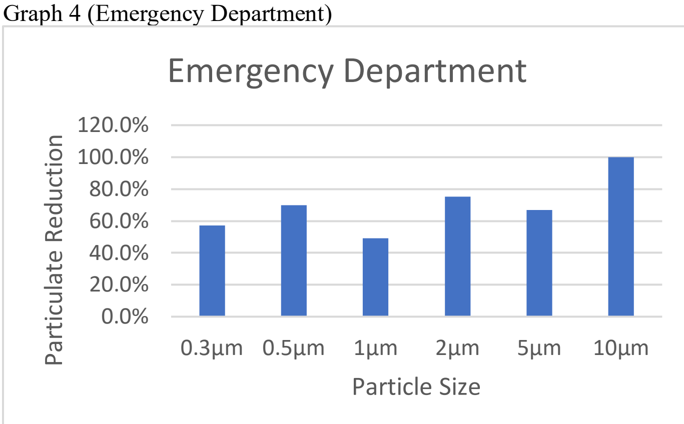

Figure 4 (Emergency Department)

	Emergency Department		
Particle Size	Before	After	Reduction
0.3	2711	1164	57.1%
0.5	508	153	69.9%
1.0	224	114	49.1%
2.0	133	33	75.2%
5.0	6	2	66.7%
10	1	0	100.0%

As with previous results, the cardiac-pulmonary administration area also received a 100% reduction in the 10µm particle size with the second highest reduction observed in the 5µm particle size (66.7%). The third highest reduction (38.1%) was observed in the 0.3µm particle size. The cardiac-pulmonary administration area saw an overall 36.2% reduction in particle counts. (Graph 5, Figure 5)

Graph 5 (Cardiac-Pulmonary Administration)

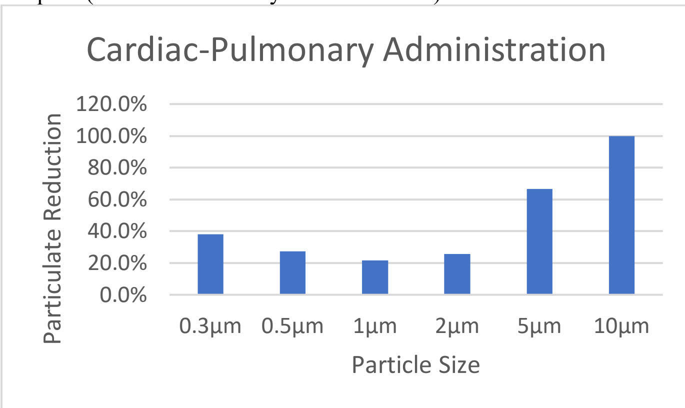

Figure 5 (Cardiac-Pulmonary Administration)

Cardiac-Pulmonary Administrative			
Particle Size	Before	After	Reduction
0.3	1842	1140	38.1%
0.5	258	187	27.5%
1.0	83	65	21.7%
2.0	35	26	25.7%
5.0	9	3	66.7%
10	1	0	100.0%

In the same area of the facility was the cardiac-pulmonary service office, also experiencing a 100% reduction in the 10µm particle size. The second largest reduction (78.6%) was observed in the 5µm particle size and the third largest particle size reduction was seen in the 0.3µm particle size (62.1%). The overall particle reduction in the cardiac-pulmonary service office was 60.9%. (Graph 6, Figure 6)

Graph 6 (Cardiac-Pulmonary Service Room)

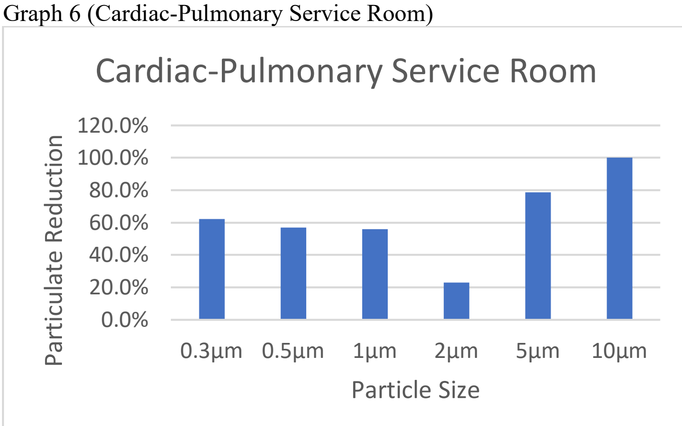

Figure 6 (Cardiac-Pulmonary Service Room)

Cardiac-Pulmonary Service Room			
Particle Size	Before	After	Reduction
0.3	1851	701	62.1%
0.5	296	128	56.8%
1.0	91	40	56.0%
2.0	26	20	23.1%
5.0	14	3	78.6%
10	1	0	100.0%

The Acute multi-specialty care room also returned a 100% reduction of 10µm particle sizes. The second highest particle reduction (87.5%) was observed in the 5µm particle size with the third highest particle reduction being 1µm (68.3%). Overall particle reduction for the acute multi-care room was 39.7%. (Graph 7, Figure 7)

Graph 7 (Acute multi-specialty care)

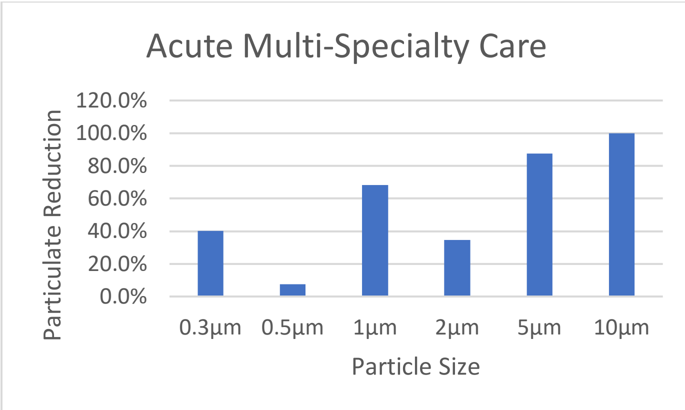

Figure 7 (Acute multi-specialty care)

Acute Multi-Service Care			
Particle Size	Before	After	Reduction
0.3	4373	2618	40.1%
0.5	633	585	7.6%
1.0	637	202	68.3%
2.0	147	96	34.7%
5.0	16	2	87.5%
10	1	0	100.0%

Another area that saw 100% reduction in the 10µm particle size was the operating room hall west area. The second highest reduction in particle size for this area was 5µm, achieving a 75.0%. The third highest reduction in particle counts was 2µm (51.2%). The overall reduction for this area was 32.3%. (Graph 8, Figure 8)

Graph 8 (Operating Room Hall West)

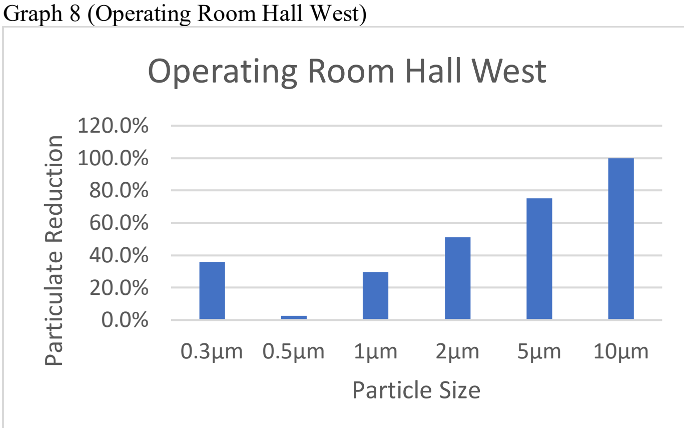

Figure 8 (Operating Room Hall West)

Operating Room Hallway West			
Particle Size	Before	After	Reduction
0.3	2293	1471	35.8%
0.5	315	307	2.5%
1.0	210	148	29.5%
2.0	82	40	51.2%
5.0	4	1	75.0%
10	1	0	100.0%

The operating room recovery saw an overall 54.9% reduction in particle counts. Consistent with all other study areas, a 100% reduction in particle counts was achieved for the 10µm particle size. The second highest reduction was 75.7% in the 2µm particle size. The third highest particle reduction was seen in the 1µm size, achieving a 73.1% reduction. (Graph 9, Figure 9)

Graph 9(Operating Recovery Room)

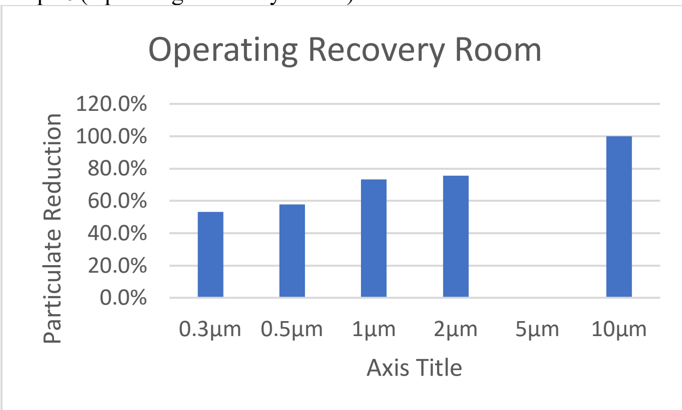

Figure 9 (Operating Recovery Room)

Operating Room Recovery			
Particle Size	Before	After	Reduction
0.3	8875	4372	53.2%
0.5	1092	461	57.9%
1.0	289	85	73.1%
2.0	144	37	75.7%
5.0	11	6	0.0%
10	11	0	100.0%

The soiled laundry area saw the greatest overall reduction in particle counts with a 64.9% reduction. As seen with other areas there was 100% reduction in the10µm particle size and 92.0% reduction in the 2µm particle size. The third greatest reduction was observed in the 5µm particle size (82.4%). (Graph 10, Figure 10)

Graph 10 (Soiled Laundry)

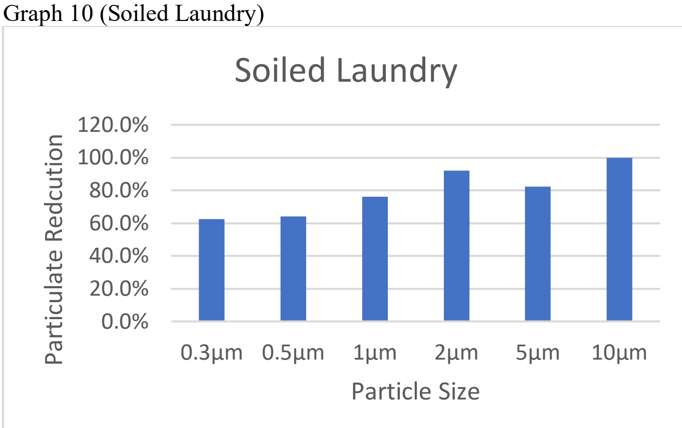

Figure 10 (Soiled Laundry)

	Soiled Laundry		
Particle Size	Before	After	Reduction
0.3	10235	3839	62.5%
0.5	2818	1011	64.1%
1.0	1014	241	76.2%
2.0	574	46	92.0%
5.0	17	3	82.4%
10	1	0	100.0%

A Pearson Coefficient Correlation test was conducted to access if there was a correlation between particle size and particle counts (Figure 11). There was a weak r-value of -0.389 in the particle counts before S400 placement and a moderate r-value of -0.408 in the particle counts after placement of S400. These values indicate there is no relationship between the variety in particle sizes present before testing or in the variety of particle sizes present after testing. This means that S400 was effective in reducing all particles sizes between 0.3 and 10µm.

Further testing was conducted to evaluate SAM's overall effectiveness at reducing particle counts, regardless of size. There was a strong correlation in the ability of S400 to reduce overall particulate counts, returning a r-value of 0.971.

Figure 11 (Correlation of Before and After Particle Counts)

	Partic~e	Before	After
ParticleSize	1.0000		
Before	-0.3895	1.0000	
After	-0.4089	0.9719	1.0000

Discussion

Although a literature review returned supporting evidence that pathogens can be found on airborne particles, this study is limited in that air sampling did not validate pathogenicity of air particle samples. Also, this study was only conducted in one hospital. The inclusion of additional facilities would have created more generalizable results.

Although S400 was effective at reducing particle counts in all test rooms, reasons for the variation in particle counts before S400 placement and after S400 placement might be due to room occupancy and use. Testing occurred under normal conditions so there were varying numbers of individuals and activities occurring in test rooms. It is likely that more populated areas with elevated activity levels may have had higher particle levels during S400 use that was not accounted for and therefore overall particle reductions may be higher. Further research is required to better understand how room occupancy and non-clinical activities contribute to the air pathogen load in health care facilities.

Conclusion

S400 was effective at reducing air particulate counts in all test rooms. This was observed whether doors remained closed in test spaces or areas were used for egress. This study confirms that S400 is a viable option to supplement healthcare ventilation systems in the reduction of air particle counts that may contain pathogens. Placement of S400 in both patient and non-patient areas of health care facilities has the potential to positively contribute to patient outcomes.

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