Emergency Care Journal 2023; volume 19:11646

The organization of ambulance decontamination during the COVID-19 pandemic: a process analysis based on the Lean Thinking philosophy

Guglielmo Imbriaco,[1,2,3] Alfonso Flauto[1,2]

[1]Prehospital Emergency Medical Dispatch Centre Emilia Est; [2]Helicopter Emergency Medical Service, Maggiore Hospital Carlo Alberto Pizzardi, Azienda USL di Bologna, Bologna; [3]Critical Care Nursing Master Course, University of Bologna, Bologna, Italy

Abstract

The COVID-19 pandemic led to massively increased emergency medical services (EMS) activity. The need to decontaminate emergency vehicles after conveying a suspected or confirmed patient to the hospital represented a critical step, slowing the activities and impacting the number of available ambulances. This brief paper analyzes the flow of EMS processes according to the Lean Thinking management approach, which focuses on reducing waste in a production cycle. The different steps of the whole process (arrival to the Emergency Department, handover phase, decontamination, return to service, and the required transfers) and a series of strategies are discussed. The organization (centralized or delocalized), number, and location of the decontamination centers impact transfers and waiting times and, consequently, the availability of ambulances. Optimizing these processes may lead to a global performance improvement, reducing transfers and time, with greater availability of emergency vehicles.

Correspondence: Guglielmo Imbrìaco, Prehospital Emergency Medical Dispatch Centre Emilia Est, Helicopter Emergency Medical Service, Maggiore Hospital, Largo Bartolo Nigrisoli 2, 40133, Bologna, Italy
Tel.: +39.0516.478111.
E-mail: guglielmo.imbriaco.work@gmail.com

Key words: emergency medical service; ambulance; decontamination; lean thinking; COVID-19.

Conflict of interest: the authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethical statement: ethical approval is not required for this contribution, as it does not involve patient data.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

Funding: this research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Received: 6 August 2023.
Accepted: 12 September 2023.
Early view: 22 September 2023.

Emergency Care Journal 2023; 19:11646
doi:10.4081/ecj.2023.11646

Introduction

Since its early beginning, the COVID-19 pandemic put incredible pressure on the healthcare industry. The massive increase in patients requiring hospital admission resulted in an overwhelming demand for emergency interventions. In addition, the pandemic has required a significant activity of inter-hospital transfers. Despite the increase in the number of ambulances, a series of factors negatively impacted their availability. The Emergency Department's (ED) overcrowding, slowdowns in triage and acceptance of patients, and the unavailability of stretchers and beds have become bottlenecks, stalling Emergency Medical Services (EMS) activities. Another significant issue during the pandemic was represented by the necessity to safeguard EMS providers and patients from the risk of viral transmission, requiring decontamination of emergency vehicles after conveying to the hospital a suspected or confirmed COVID-19 patient.

The main objective of this concept article is to analyze different decontamination processes at a system level from the Lean Thinking perspective, evaluating the most relevant problems and discussing possible strategies to mitigate them. To provide a wider generalization, the present concepts are hypothesized in an urban EMS system; specific settings or other EMS areas (e.g. rural or remote) may have managed the decontamination processes with different approaches and solutions.

Discussion

The Lean Thinking management approach

Optimization of production processes and continuous quality improvement represent fundamental elements of each organization in today's world. One of the most popular methods used to improve efficiency and performance is the Lean Thinking approach, derived from the Toyota production system and widely spread since the beginning of the 2000s.[1,2]

Lean Thinking is a management philosophy that integrates social and technical aspects; its main aim is to understand processes to identify and analyze problems and focus on eliminating waste, defined as any activity that requires time and resources without adding value to the final product.[3,4] The seven categories of waste are overproduction, inventory (unnecessary stock), motion (non-ergonomic work environment), mistakes and errors, over-processing (unnecessary or duplicated work), waiting (bottlenecks in the process), and transportation over long and unnecessary distances.[4,5] Over the last 20 years, the Lean approach has been extended to the healthcare context, increasing appreciation by patients and other stakeholders through the evaluation and the improvement of every step in the patient pathway.[4-6] Several studies and reviews reported that implementing Lean Thinking in healthcare has contributed to reducing discharge time and hospital length of stay while improving patient and staff satisfaction.[7,8] The application of Lean concepts in the ED showed a global performance improvement, with an increased patient volume and decreased waiting times, length of stay, and proportion of patients leaving without being seen.[9,10]

A Lean Thinking analysis of ambulance decontamination methods and processes

Like any other productive context, EMSs work in a constant balance between demand, the requests for emergency interventions, and delivery of the final service, the dispatch of ambulances, medical cars, or helicopters. EMS activities can be seen as a circular flow, beginning with the dispatch of emergency vehicles and ending with the delivery of the patient to the emergency room, getting back in service. A further step is represented by restoring the material used and cleaning and reorganizing the vehicle for the subsequent intervention.

A process that slows down the flow and can represent a critical factor is the decontamination of ambulances, which is necessary after transporting one or more COVID-19 patients. The decontamination requires to be preceded by a manual cleaning phase, to remove visible dirt, followed by sanification and disinfection, generally obtained by nebulizing a chemical solution or through ultraviolet light-based lamps. Nebulized agents seem to have greater efficacy, due to their capability of penetrating areas difficult to reach with a regular cleaning procedure, providing a sealed closure of ambulance cabins.[11] Notably, adequate ventilation time is required after the use of chemical products. Depending on the employed method, the decontamination process requires approximately 20 to 30 minutes to complete (including 10-15 minutes of aeration, when required).

The most used decontamination systems are based on ozone, sodium hypochlorite, and hydrogen peroxide. Ozone is an unstable gas derived from oxygen; its oxidizing properties eliminate gram-positive and negative bacteria, yeasts, and viruses from objects, tissues, and surfaces. Ozone generators should be able to achieve an adequate concentration (up to 25 ppm) in the ambulance patient's compartment (about 8-16 m^3 depending on the model);[12] small, portable ozone generator devices may require longer times to achieve saturation. Ozone turns back into oxygen in a few minutes, leaving no residuals.

Sodium hypochlorite is a commonly used disinfecting agent; depending on its concentration (typically 0.1%), it may inactivate viruses and other germs within one minute of exposure. Its main drawbacks are related to the risks for individuals and the corrosive effect on metals (e.g. stretchers).

Hydrogen peroxide nebulizers produce a mist effective against a range of enveloped and non-enveloped viruses. Hydrogen peroxide decomposes into water and oxygen, thus reducing the risk of oxidizing medical equipment.[13]

Ultraviolet (UV) irradiation is a simple disinfecting and sterilizing method, based on the emission of UV light at a certain wavelength; its effect damages the nucleic acid and consequently inhibits germs replication. UV systems are simple and have the great advantage of not leaving residuals; the main risks are related to skin and eye exposure when using specific UV wavelengths. The main limitation is that UV systems are less effective on surfaces that are not directly exposed to light emitters.[14]

Photocatalysis is based on the interaction of light at adequate frequency with electron-releasing photoactive materials (e.g. titanium dioxide), leading to an oxidative process that physically damages virus cell walls.[15] These reactions work continuously, thanks to the effect of solar or artificial light; on the other hand, photocatalysis requires ambulance interiors built with specific materials and it is not available on existing models. In the future, this promising method may help reduce decontamination times.

Each method used must consider not only costs and availability but also the possible damage to the ambulance cabin and device materials (e.g. plastic, fiberglass, metals). An overview of the main ambulance decontamination methods, reporting key concepts and approximate times required (i.*e*. decontamination and aeration) is described in Table 1.[16]

The organization (centralized or delocalized), number, and location of the decontamination centers impact transfers and waiting times and, consequently, the availability of ambulances. The Authors identified a total of five situations, generalizable to an urban EMS system, highlighting the various steps following ED arrival (triage/handover, decontamination) and the transfer times between the different processes until the ambulance returns to its EMS station, ready and available for a new mission.

Centralized hub: a single large decontamination hub in an urban area, capable of multiple cleaning treatments at the same time. Transfer times from the ED and to the ambulance station may vary in distances and traffic (e.g. daytime versus nighttime). A centralized decontamination hub requires dedicated personnel.

Hospital-based: decontamination services are located near hospitals, reducing transfer times from the ED. This approach requires a greater number of decontamination services, even if established only in the biggest hospitals, and may require dedicated personnel.

Ambulance station: decontamination services are located at ambulance stations, zeroing transfer times following the cleaning process.

Ongoing/onboard decontamination: decontamination devices in the patient care compartment of the ambulance allow for performing the decontamination process en route, while the crew returns to the station.

ED/Triage: dedicated personnel decontaminate ambulances during the Triage/handover phase, while EMS providers transfer patients and report handover to ED nurses. This approach eliminates transfers to a decontamination facility (centralized hub, hospital-based, or to the ambulance station) and allows to have ambulances ready and available in shorter times. On the other hand, it requires dedicated personnel. A similar option was adopted by a few EMS systems, involving a driver who delivers a clean ambulance and collects the used one during the Triage phase; this strategy requires a well-organized structure and an adequate number of vehicles and personnel.

As depicted in Figure 1, decontamination procedures can be performed at a variety of locations. This may result in different durations of the entire process (from ED arrival to the return of the ambulance at its station, clean and sanitized), ranging from a maximum of 80 minutes of the centralized decontamination hub to a minimum of 40 minutes when performed during the ED/Triage phase. Notably, the time required to complete the disinfection and have the ambulance ready and available, even if not at its station, is significantly lower, with a maximum of 65 minutes and a minimum of 25 minutes when performed at the ED.

Main features and concerns of ambulance decontamination processes

A decontamination hub requires a large structure (including an area for aeration) with dedicated personnel and is capable of multiple simultaneous vehicle treatments. Even considering its advantages in terms of productivity, similar to a "decontamination assembly line", this strategy may be expensive. Moreover, it is necessary to consider the time required to reach the facility, which may vary according to distance and traffic.

Setting up decontamination facilities within hospital areas reduces ambulance transfer times; however, not every hospital has adequate spaces available (vehicle bays, covered parking, or outdoor areas where to install decontamination tents). Contrarily, ambulance stations can accommodate a decontamination area in the vehicle bays, paying attention to ensuring adequate ventilation (particularly when using chemical agents, like sodium hypochlorite or hydrogen peroxide). In both cases, without dedicated staff, decontamination procedures must be carried out by EMS providers.

The ongoing/onboard approach requires dedicated devices that sanitize the patient care compartment when the ambulance is moving. These decontamination systems may reduce the total process time but require preventive manual cleaning and disinfection of the surfaces (usually performed by EMS personnel). Costs are variable, depending on whether the device is mobile or fixed, installed in the patient compartment. Notably, ambulances with integrated

Table 1. Overview of ambulance decontamination methods.

Decontamination agent	Main features	Advantages	Disadvantages	Decontamination time (in minutes)	Aeration (in minutes)
Ozone gas	Powerful oxidative agent; eliminates germs, viruses and microbes	Leaves no chemical or polluting residues	Unstable at room temperature	15-20	5-10
Sodium hypochlorite (aerosolized)	High-level disinfectant agent effective against most viruses and bacteria	Significantly reduces the infectivity of SARS-CoV-2 on surfaces within 1 minute of exposure	Leaves polluting residuals	15-20	5-10
Hydrogen peroxide (aerosolized)	Viral inactivation	Versatility, high safety	The effective and safe use of hydrogen peroxide depends on the concentration and decontamination time	15-20	5-10
Ultraviolet (UV) light	UV light radiation at specific wavelengths eliminates microorganisms	Non-chemical process, leaves no residues	Low penetration Dose dependent Material dependent Requires a minimum distance between UV source and surfaces Energy consumption and lamp cost (replacement required every 8,000 hours) Depends on environmental conditions (relative humidity) Attention required for the risk of skin and eyes exposure	10-30	Not required
Photocatalysis (UV + titanium dioxide)	Titanium dioxide surfaces release electrons when illuminated by UV light. These electrons interact with water molecules, resulting in highly-reactive hydroxyl radicals which degrade the organic structure of viruses and bacteria.	Non-polluting system, works through natural or artificial light	High production costs. Not applicable to existing ambulances.	Continuous process	Not required

decontamination systems have an additional cost.

Ambulance decontamination during the Triage phase, when EMS teams unload patients and report handovers to ED nurses, seems the most effective strategy. This approach overcomes three of the seven wastes of the Lean Thinking philosophy (waiting, motion, and transportation), overlapping the decontamination process to the waiting time during the Triage phase. In addition, moving vehicles to a decontamination facility is not necessary, reducing waste of time and costs. This approach can be compared to car wash services that have spread in the last years in parking lots near supermarkets or cinemas, getting vehicles clean while people shop or watch a movie.

Another issue to consider is a rest period for EMS providers. Working with full personal protective equipment (PPE), particularly when treating critically ill patients with high temperatures, is physically challenging and may lead to fatigue, migraines, and other health problems.[17,18] A delocalized decontamination hub may require EMS providers to remain donned with PPE along the way. The process should also consider a quote of time for physical restoration, especially if EMS teams are the ones entrusted to the ambulance decontamination.

Limitations

The above-mentioned analysis was focused on the ambulance decontamination process and did not consider the first part of an emergency mission (emergency call and dispatch, reaching the target, and interventions performed by EMS providers). The times of the various steps of the decontamination process are an average estimation based on the different devices available and the Authors' experience during the pandemic. Moreover, the Authors decided not to discuss the procedures adopted by every EMS dispatch center to face the increased number of interventions during the pandemic, particularly when ambulances had to perform decontamination (e.g. after [a] two consecutive interventions for confirmed COVID-19 patients or [b] one intervention for a suspect patient followed by a confirmed one).

The main aim of this paper was to analyze the decontamination processes of ambulances and rescue vehicles, synthetically describing the decontamination techniques. A full and comprehensive review of the currently available decontaminating agents and devices (including germicidal efficacy, cost, and other pros and cons) would be desirable because of the importance of this topic for the whole healthcare industry.

Conclusions

The Lean Thinking philosophy focuses on doing the right thing at the right time and removing steps that don't add value to a production cycle. This management approach could be applied to a wide range of production environments, including the healthcare setting. Emergency medical services could benefit from the com-

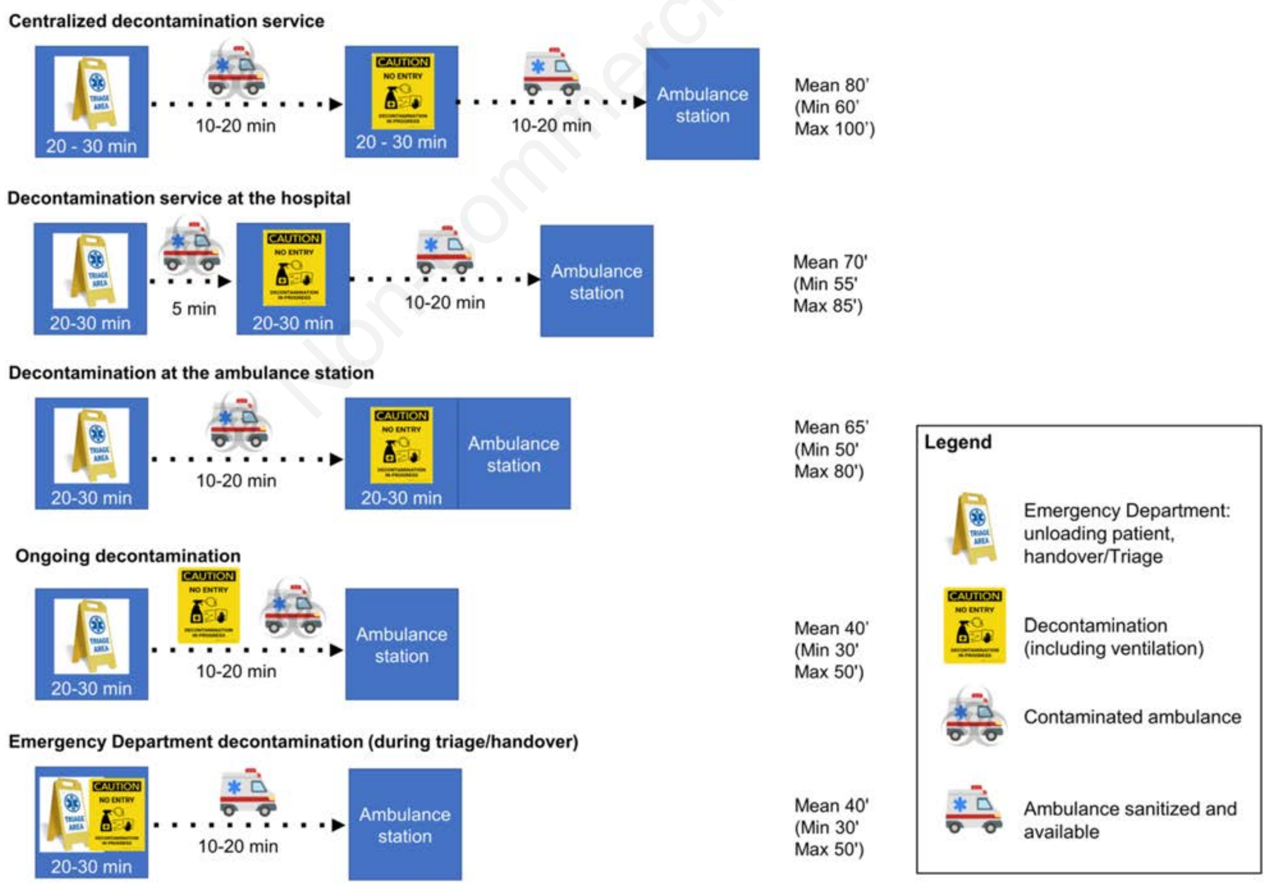

Figure 1. Visual representation of ambulance decontamination strategies.

prehension of the different organizations and strategies to perform ambulance sanification. When possible, the application of these concepts could contribute to optimizing the whole process, minimizing unnecessary transfers, and reducing the time to complete the procedure, indirectly increasing the number of available EMS responding units.

References

1. Lawal AK, Rotter T, Kinsman L, et al. Lean management in health care: definition, concepts, methodology and effects reported (systematic review protocol). Syst Rev 2014;3:103.
2. Deblois S, Lepanto L. Lean and Six Sigma in acute care: a systematic review of reviews. Int J Health Care Qual Assur 2016;29:192-208.
3. Rotter T, Plishka C, Lawal A, et al. What Is Lean Management in Health Care? Development of an Operational Definition for a Cochrane Systematic Review. Eval Health Prof 2019;42:366-390.
4. Prado-Prado JC, García-Arca J, Fernández-González AJ, Mosteiro-Añón M. Increasing Competitiveness through the Implementation of Lean Management in Healthcare. Int J Environ Res Public Health 2020;17:4981.
5. Sheperd CC. Lean for Government: Eliminating the Seven Wastes. NTRS-NASA Technical Reports Server. January 1, 2012. Accessed October 8, 2022. Available from: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120016881.pdf
6. Breen LM, Trepp R Jr, Gavin N. Lean Process Improvement in the Emergency Department. Emerg Med Clin North Am 2020;38:633-646.
7. Zepeda-Lugo C, Tlapa D, Baez-Lopez Y, et al. Assessing the Impact of Lean Healthcare on Inpatient Care: A Systematic Review. Int J Environ Res Public Health 2020;17:5609.
8. Tlapa D, Zepeda-Lugo CA, Tortorella GL, et al. Effects of Lean Healthcare on Patient Flow: A Systematic Review. Value Health 2020;23:260-273.
9. Holden RJ. Lean Thinking in emergency departments: a critical review. Ann Emerg Med 2011;57:265-78.
10. Bucci S, de Belvis AG, Marventano S, et al. Emergency Department crowding and hospital bed shortage: is Lean a smart answer? A systematic review. Eur Rev Med Pharmacol Sci 2016;20:4209-4219.
11. Baldovin T, Amoruso I, Paganini M, et al. SARS-CoV-2 Contamination of Ambulance Surfaces and Effectiveness of Routine Decontamination Procedure: A Classic Hygiene Lesson for A Novel Pathogen. Int J Environ Res Public Health 2022;19:13646.
12. Gómez-Castillo MA, Rivera Romero C, Reátegui-Ochoa K, et al. Ozone Efficacy for the Disinfection of Ambulances Used to Transport Patients during the COVID-19 Pandemic in Peru. Int J Environ Res Public Health 2023;20:5776.
13. Estienney M, Daval-Frerot P, Aho-Glélé LS, et al. Use of a Hydrogen Peroxide Nebulizer for Viral Disinfection of Emergency Ambulance and Hospital Waiting Room. Food Environ Virol 2022;14:217-221.
14. Lindsley WG, McClelland TL, Neu DT, et al. Ambulance disinfection using Ultraviolet Germicidal Irradiation (UVGI): Effects of fixture location and surface reflectivity. J Occup Environ Hyg 2018;15:1-12.
15. Kumar A, Hasija V, Sudhaik A, et al. The practicality and prospects for disinfection control by photocatalysis during and post-pandemic: A critical review. Environ Res 2022;209:112814.
16. Istituto superiore di sanità. Raccomandazioni ad interim sulla sanificazione di strutture non sanitarie nell'attuale emergenza COVID-19: ambienti /superfici. Rapporto ISS COVID-19 n. 12/2021. Accessed October 12, 2022. Available form: https://www.iss.it/documents/20126/0/Rapporto+ISS+COVID-19+12_2021.pdf
17. Galanis P, Vraka I, Fragkou D, Bilali A, Kaitelidou D. Impact of personal protective equipment use on health care workers' physical health during the COVID-19 pandemic: A systematic review and meta-analysis. Am J Infect Control 2021;49:1305-1315.
18. McCann-Pineo M, Li T, Barbara P, et al. Factors Influencing Use of Personal Protective Equipment Among Emergency Medical Services Responders During the COVID-19 Pandemic: A Retrospective Chart Review. West J Emerg Med 2022;23:396-407.