ORIGINAL ARTICLE

The route of healthcare-associated infections using tracer methodology and modeling by complex networks

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ABSTRACT

Background and Objectives: surgical site infections (SSI) comprise approximately 15% of healthcare-associated infections (HAIs) in Brazil. This study assessed the route of infections using tracer methodology, aligned with analysis by complex networks, by tracing a patient (case) who underwent surgery (scenario). **Methods:** an observational and descriptive case study, with cross-sectional and retrospective assessment, by tracing and analyzing the medical records of a patient who underwent surgical procedures. Tracer methodology was used from the perspective of complex networks at *Hospital das Clínicas*, *Universidade Federal de Pernambuco*. **Results:** a woman, 65 years old, submitted to decompression, arthrodesis, and graft removal (donor) in the left iliac. Readmitted with left iliac osteomyelitis, worsening in general condition, followed by death. The priority factor (PFP) related to the case was the surgical procedure to remove the graft in the left iliac, by the orthopedic clinic. According to the Brazilian Manual of Hospital Accreditation, the mandatory and applicable standards according to hospital profile have the following percentages of conformity for level 1 (78.7%), level 2 (82.4%), and level 3 (51.7%). Using complex networks and considering that professionals are potential carriers of the spread of infections and are predictors of the spread of SSI (scenario 2/hypothesis 2) plus the lack of structure for hand hygiene (scenario 3/hypothesis 3), it was observed that there is a greater chance that SSI occurred in ward and ICU. **Conclusions:** the probable spread of HAIs is related to professionals and the physical-functional structure necessary to provide safe care.
KEYWORDS: Patient Safety; Medical Errors; Cross Infection; Surgical Wound Infection.

RESUMO

Justificativa e Objetivos: no Brasil, infecções de sítio cirúrgico (ISC) compreendem aproximadamente 15% das infecções relacionadas à assistência à saúde (IRAS). Este estudo avaliou a dinâmica das infecções por meio da metodologia *tracer*, alinhada à análise por redes complexas, utilizando o rastreamento de um paciente (caso) que foi submetido à cirurgia (cenário). **Métodos:** estudo de caso, de natureza observacional, abordagem descritiva, com avaliação

transversal e retrospectiva, pelo rastreamento e análise do prontuário de um paciente submetido a procedimentos cirúrgicos, utilizando a metodologia *tracer*, sob a ótica das redes complexas, no Hospital das Clínicas, Universidade Federal de Pernambuco. **Resultados:** mulher, 65 anos, submetida à descompressão, artrodese e retirada de enxerto (doador) em ilíaco esquerdo. Readmitida com osteomielite do ilíaco esquerdo, evoluindo com piora do estado geral, seguido de óbito. O fator de prioridade (PFP) relacionado ao caso foi o procedimento cirúrgico para retirada do enxerto no ilíaco esquerdo pela clínica ortopédica. De acordo com o Manual Brasileiro de Acreditação Hospitalar, os padrões obrigatórios e aplicáveis, segundo o perfil do hospital, apresentam os seguintes percentuais de conformidade para o nível 1 (78,7%), nível 2(82,4%) e no nível 3 (51,7%). Utilizando as redes complexas e considerando que os profissionais são potenciais carreadores da disseminação das infecções aos suscetíveis e são preditores da propagação da ISC (cenário 2/hipótese 2), somado à falta de estrutura para higienização das mãos (cenário 3/hipótese 3), observou-se que há maior chance de ISC ter ocorrido nos setores da enfermaria e UTI. **Conclusões:** a provável propagação das IRAS está relacionada aos profissionais e à estrutura físico-funcional necessária para prestação da assistência segura.
PALAVRAS-CHAVE: Segurança do Paciente; Erros Médicos; Infecção Hospitalar; Infecção da Ferida Cirúrgica.

RESUMEN

Justificación y objetivos: en Brasil, la ocurrencia de infecciones en pacientes hospitalizados es aproximadamente 15%, y, por eso, la importancia de estudiar la dinámica de las infecciones hospitalarias. Este estudio evaluó la dinámica de las infecciones utilizando la metodología *tracer*, alineada con el análisis por redes complejas, a partir del rastreo de un paciente (caso) sometido a procedimientos quirúrgicos (escenario). **Métodos:** estudio de caso, de naturaleza observacional, abordaje descriptivo, con evaluación transversal y retrospectiva, a partir del rastreo individual utilizando la metodología *tracer*, a través del análisis de prontuario de un paciente sometido a procedimientos quirúrgicos en la Clínica de Ortopedia, *Hospital das Clínicas*, *Universidade Federal de Pernambuco*. **Resultados:** una mujer, 65 años, sometida a descompresión, artrodesis y retirada de injerto en ilíaco izquierdo. Leído con osteomielitis del ilíaco izquierdo, evolucionando con empeoramiento progresivo del estado general, seguido de muerte. El factor de prioridad (PFP) relacionado con el caso fue el procedimiento quirúrgico para la extracción del injerto en el ilíaco izquierdo, por la clínica ortopédica. Los porcentajes de conformidad en el nivel 1 correspondió al 78,7%, en el nivel 2 fue 82,4% y en el nivel 3, 51,7%. A partir del análisis por redes complejas, se observó que hay mayor probabilidad de que la diseminación de la infección esté relacionada con el conjunto de contactos, siendo los profesionales los potenciales portadores de las infecciones a los susceptibles, en los sectores de la enfermería y UTI, siendo éste el predictor de la propagación de la infección de sitio quirúrgico (Escenario 2/Hipótesis 2) y/o la falta de estructura para higienización de las manos (Escenario 3/Hipótesis 3). **Conclusiones:** las fuerzas que impulsan las infecciones hospitalarias están relacionadas a los cuidadores ya la estructura físico-funcional necesaria para el desarrollo de la asistencia a la salud.
PALABRAS-CLAVE: Seguridad del Paciente; Errores Médicos; Infección Hospitalaria; Infección de la Herida Quirúrgica.

INTRODUCTION

Healthcare-associated infections (HAIs) are described as a serious public health problem and are associated with high rates of morbidity and mortality. Among the healthcare-associated adverse events (AE), HAIs are among the most frequent. In developing countries, 10 out of every 100 hospitalized patients will develop at least one HAI and surgeries account for 1/3 of this estimate.[1,2]

A continuous surveillance program can reduce the rates of surgical site infections (SSI) by 30 to 40%, provided that tracing these infections and associated risk factors is effective. [3,4]

Tracer is a methodology used to trace the path of patients in the service network. It allows cross-checking and multi-professionally checking the routes established for care; and also promotes the audit of Priority Focus Processes (PFP) related to risk management and patient safety. [5,6,7]

From the perspective of modeling by complex networks, it is possible to understand the transmission route of HAIs; and, associated with tracer methodology, it is possible to visualize the vertices formed in this network. The dynamic mechanism, in free-scale networks, brought the possibility to understand the trajectory and the epidemiological process of infectious diseases through mathematical models.[8] When this model is applied to the routes of HAIs, it is possible to calculate the probabilities of a susceptible being linked to an infected person within this network.

In this regard, this study aims to assess the route of infections using tracer methodology, aligned with analysis by complex networks, by tracing of a patient (case) who underwent surgery (scenario).

METHODS

This is an observational and descriptive case study, with cross-sectional and retrospective assessment, based on tracer methodology.[6,7] The case was selected after a serious AE at the Orthopedics Clinic, whose historical series showed a high SSI rate. The case was traced by analyzing the medical records of a patient who underwent surgery at the Orthopedics Clinic of *Hospital das Clínicas, Universidade Federal de Pernambuco* (HC/EBSERH/UFPE).

The study took place at a high-complexity university hospital, with a capacity of 407 beds, in a 62,000 m^2 area. It is worth mentioning that this hospital has a Patient Safety Center (*Núcleo de Segurança do Paciente*, abbreviated NSP) formally constituted in July 2014. The hospital followed the norms of Ordinance/MoH 529 of April 1, 2013, which instituted the Brazilian National Health Safety Program (*Programa Nacional de Segurança do Paciente*, abbreviated PNSP) and ANVISA Board Resolution (RDC) 36 of July 25, 2013. RDC establishes actions for patient safety in health services.[13] Risk management began in 2016 with the establishment of the Assistance Risk Management Unit (ARMU).

Tracing was carried out using Priority Focus Processes (PFP), considering that these areas are systems or structures located within healthcare organizations that significantly affect patient care safety and quality. PFP are part of the dynamics of assessment by tracer for outlining a case from a particular focus or problem situation. PFP is an open activity, defined from Priorities and Focus Areas (PFA).[7]

The priority factor related to the case under study was the surgical process for removal of graft in the left iliac artery (PFP), considering it is an intervention performed by the orthopedics clinic (PFA). The steps followed by the patient in the hospital were traced, considering the surgical interventions received, tests performed, and AE.

The areas covered in the Brazilian Manual of Hospital Accreditation (*Manual Brasileiro de Acreditação Hospitalar*) were traced and the following standards were assessed: A) Mandatory standards: I. General organization of the hospital; II. Physical-functional structure; III. Organization of patient care; IV. Diagnostic and therapeutic support services; B) Standards applicable according to hospital profile. All standards were assessed according to the level. Level 1 (L1) corresponds to the minimum requirements for providing care; level 2 (L2) is related to quality of care standards, given best care practices; and level 3 (L3) comprises when the institution reaches the standards of excellence in providing medical and hospital care.[9]

For data interpretation, we used the Conformity Index (CI), established by the Joint Commission International (JCI). Based on JCI standards, the ideal CI is ≥80% for all indicators and reflects safety in relation to care provided.[10] The ideal CI (≥80%) was based on Positivity Index (PI), which establishes the following standards: 100% positivity means that the item analyzed was 100% correct or conformant, corresponding to a desirable care; 99 to 90%, adequate care; 89 to 80%, safe care; 79 to 70%, borderline care; less than 70% indicates unwanted or poor care.[11]

After performing tracer, all vertices (nodes) related to HAIs acquired by the patient were defined. The following scenarios and hypotheses were considered for vertex analysis:

Scenario 1: development of SSI in a hospitalized patient in an Orthopedic Surgical Clinic Unit.

Hypothesis 1: surgical site is a continuity solution for HAI development.

Scenario 2: the spread of the disease among patients (of infection), with the spread of trust among health professionals.

Hypothesis 2: professionals who provide direct care to patients can be predictors of the spread of SSI.

Scenario 3: lack of structure for hand hygiene promotes the spread of infection among patients in the same clinic or sector.

Hypothesis 3: physical structure does not contribute to best practice and favors the spread of infection from person to person.

Data were collected between April and July 2017; were recorded in spreadsheets in the Microsoft Excel® program, 2013, to form a database and tabulation. To analyze the association of independent variables (age, pre-existing diseases, number of beds/sector, number of admissions/sector, number of caregivers/sector, length of stay, length of hospital stay, number of contacts in the care network, number of susceptible patients, number of infected patients/sector and number of sinks for hand hygiene) with SSI, complex network modeling was used, assessing the nodes and edges that form and the network design.

To perform analysis in light of complex networks, the following standards were used: prevalence values (π); infectivity (γ); probability of infection (P), considering the number of contacts (C); susceptible patients (S); and infected patients (I). All calculations were performed based on the study conducted by Ferreira and Torman, 2013[12]. For prevalence, the formula used was $\pi = I/C$; for infectivity, $\gamma = I * S/C$; and for probability, $P=1-(1-\pi*\gamma)^C$. The expected number of infected contacts was also calculated using the formula $E(Ci) = 1/\pi * \gamma$ and the probability of infection adjusted for length of stay (Pp), considering $Pp = P * Td$; Td represents stay in days.

The SSI rate in the hospital cohort (dependent variable) was considered as the primary outcome. The strength of association of these infections with the established independent variables (risk factors) such as length of stay, readmissions, and sectors where the patient went, was considered as the second outcome.

This research is part of "*Projeto Modelagem por redes complexas da dinâmica das infecções hospitalares em pacientes submetidos à intervenção cirúrgica em um Hospital de Ensino*

Federal no Estado de Pernambuco"; and it was developed according to the rules recommended in the Resolution of the Brazilian National Health Council (*Conselho Nacional de Saúde*, abbreviated CNS) 466/12, according to CAAE (*Certificado de Apresentação para Apreciação Ética* - Certificate of Presentation for Ethical Consideration) 65505817.1.0000.5208 and Consubstantiated Opinion 2,006,067 of April 7, 2017.

RESULTS

The Case

N.M.V.V., 65 years old, female, mixed-race, psychologist, divorced, born and living in Recife, PE, admitted to the university hospital on November 13, 2016 (1st admission). History of low back pain and irradiation to the right lower limb. Magnetic resonance imaging was performed, which revealed L2-L3 and L5-S1 herniated discs and L2-L3 degenerative discopathy. On November 14, decompression and arthrodesis was performed 360 degrees in L2-L3, and graft was removed in the left iliac. In the postoperative period, she maintained strength and sensitivity of the limbs and reflexes without alterations, diuresis and evacuations present, surgical wound (SW) clean and well coaptized. She was discharged on November 17.

She returns on December 1, 2016 (2nd admission) with pain and secretion in SW (removal of graft from the left iliac). She underwent surgical cleaning, culture, and antibiotic therapy (meropenem and vancomycin) was started for 9 days. Then, she received ciprofloxacin for treatment at home (done for 42 days). She was discharged on January 11, 2017.

On March 19, 2017 (3rd admission) with osteomyelitis of the left iliac, she presented a local fistula with signs of SSI, performed a fistulectomy on March 26 and started antibiotic therapy (vancomycin and meropenem) without cultures. Surgical cleaning was performed in SW (seven times) under sedation in the operating room. On April 13, she developed dyspnea associated with hypoxemia and cough and was referred to the Intensive Care Unit (ICU), with suspected pneumonia/PTE. Bone fragment culture showed *Acinetobacter baumannii*, and was guided to change antibiotics (polymyxin B, amikacin, and tigecycline). She was diagnosed with Respiratory Tract Infection (RTI), and antibiotic therapy (meropenem) was started. On April 13, she underwent computed tomography (CT) of the chest with contrast, showing pulmonary nodules. On May 2, pulmonary segmentectomy was performed by video laparoscopy (VDL), histological diagnosis of

Obliterating Bronchiolitis with Organizing Pneumonia (OBOP). Corticosteroid therapy (80 mg/day) was initiated, as recommended by pulmonology, and vitamin B12 replacement due to reducing gastroplasty (2011). She stabilized and was discharged from the ICU on May 10.

She was hemodynamically stable, with improvement of dry cough and diuresis present by delayed bladder catheter (DBC), and progressed to leukocytosis and thrombocytopenia. On May 21, she was readmitted to the ICU due to clinical worsening, hyperlactemia, drop in saturation, dyspnea, hypotension; therefore, it was suggested to change the antibiotic regimen (meropenem, teicoplanin and amphotericin B). She had a severe condition, refractory shock when using vasoactive drugs (DVA 65 ml/hour), lactated ringer serum and albumin. On May 23, 2017, she was hemodynamically unstable with cold extremities and impaired perfusion. At 2 hours and 15 minutes, she had a cardiopulmonary arrest, resuscitation maneuvers were started, without success, and death was confirmed.

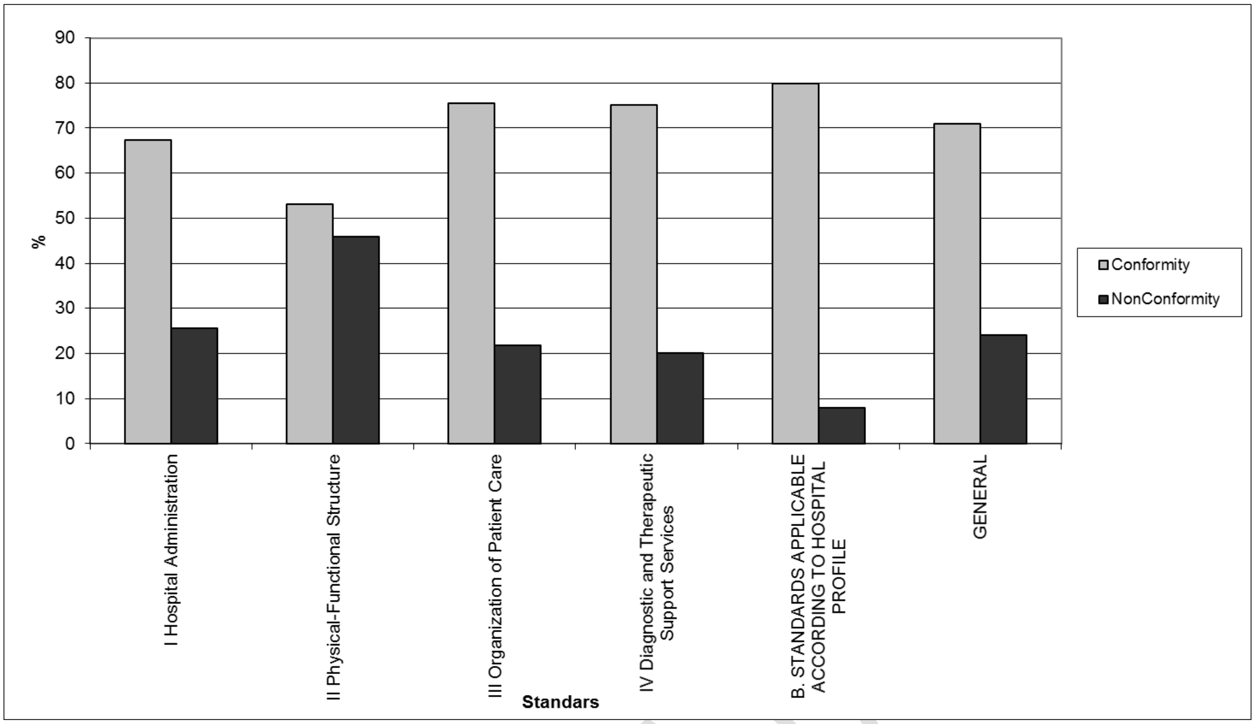
Tracer methodology

Tracing was carried out in the sectors where the patient received some type of care and in the related systems/services. Aspects related to hospital administration, physical-functional structure, organization of care, diagnostic and therapeutic support services and specific standards (services) applied to the case were assessed. For all items, the percentage of conformity (C) was higher than that of nonconformity (NC); however, it is worth noting that, for the physical-functional structure, NC was 46% (Graph 1; Table 1).

If conformity percentages by level are considered, at level 1, this value corresponded to 78.7%; at level 2, it was 82.4%; and at level 3, it was 51.7%. In other words, there was a tendency to improve the quality standard at level 2, but not linear, due to the drop in level 3, therefore far from the level of excellence.

In the global assessment, the mean percentage of conformity, considering all standards analyzed, was 70.9%, with care being placed on a borderline scale and close to poor (Graph 1).

Graph 1. Standards assessed according to the CI established by JCI at HC/EBSERH/UFPE from April to July 2017



The level of conformity points to where the root of the problem for SSI to progress probably is. It is worth noting that the standard related to physical-functional structure had the lowest rate of conformity (C=53.1%), followed by hospital administration (67.3%). It is observed that there is an attempt to organize care (CI=75.6) and support services (CI=75.1); however, such efforts seem to be faced with lack of a minimum structure necessary for quality assurance (Table 1).

Table 1. Standards assessed by level of excellence according to the CI established by JCI at HC/EBSERH/UFPE from April to July 2017

	Levels	Standard of Conformity	
A. MANDATORY STANDARDS			
I) HOSPITAL ADMINISTRATION		**C**	**NC**
	%L1	69.8	26.0
	%L2	78.7	18.7
	%L3	53.4	31.8
	%Mean	**67.3**	**25.5**
II) PHYSICAL-FUNCTIONAL STRUCTURE			
	%L1	67.1	32.9
	%L2	67.1	30.0
	%L3	25.0	75.0

	%Mean	**53.1**	**46.0**
III) ORGANIZATION OF PATIENT CARE			
	%L1	88.8	11.2
	%L2	81.5	14.9
	%L3	56.4	39.5
	%Mean	**75.6**	**21.9**
IV) DIAGNOSTIC AND THERAPEUTIC SUPPORT SERVICES			
	%L1	87.0	13.0
	%L2	91.7	8.3
	%L3	46.7	38.9
	%Mean	**75.1**	**20.1**
B. STANDARDS APPLICABLE ACCORDING TO HOSPITAL PROFILE			
	%L1	72.1	4.5
	%L2	89.1	7.0
	%L3	78.6	12.5
	%Mean	**80.0**	**8.0**
GENERAL			
	%L1	78.7	15.4
	%L2	82.4	15.1
	%L3	51.7	41.5
	%Mean	**70.9**	**24.0**

Caption: L1 - level 1, corresponding to the minimum requirements to provide care; L2 - level 2, related to the quality of care standards, given best care practice; L3 - level 3, when institution reaches the standards of excellence in providing medical and hospital care. C - conformity; NC - nonconformity.

Analysis in light of complex networks

To map the complex network, all services that provided assistance to the patient (case) were assessed, such as: operating room (OR); Post-Anesthetic Care Unit (PACU); ward (WAR.); intensive care unit (ICU); hemodynamic service. It was observed that there was a longer stay in the ward (41 days on the 1st admission; 25 days on the 2nd admission) and also possible contacts (61 caregivers and 167 patients). However, it was the highest occurrence of infection/colonization in the ICU during this patient's stay (11 occurrences; 9 microorganisms identified).

Table 2 summarizes these results and the elements that make up the complex network of this case.

Table 2. Structuring elements of the infection dissemination network in the case analyzed from April to July 2017 at HC/EBSERH/UFPE

Standards	Sectors					
	OR	**PACU**	**WAR.**	**ICU**	**HEMO-DYNAMICS**	**PACU/ HD[V]**
Number of beds occupied/sector	8	6	36	10	1	6
Number of new admissions in all sectors where the patient was assisted[(I)]	9	9	4	2	1	1
Length of stay/sector						
1st Admission	390 min.	-	4 days	0	0	-
2nd Admission	75 min.	-	41 days	0	0	-
3rd Admission	348 min.	-	25 days	28 days	30 min.	-
Total number of caregivers/sector[(II)]	61	3	61	77	6	4
Nursing service	58	3	36	42	3	3
physicians[(III)]	3	-	4	17	3	1
Physiotherapists	0	0	14	16	0	0
Nutritionist/pantry worker	0	0	6	1	0	0
Speech therapists	0	0	1	1	0	0
Number of patients per sector[(IV)]	90	63	167	31	0	-
Number of hand hygiene sinks/sector	6	1	1	2	1	1
Occurrence of infection/colonization by sector during the length of stay[(VI)]	0	0	4	11	0	0

Caption: OR - operating room; PACU - Post-Anesthetic Care Unit; WAR. - Ward; Min - minutes. (I) Considering the number of times there was admission to the sectors (OR, PACU, WAR, ICU, Hemodynamics, and PACU/HD) multiplied by the number of beds occupied. (II) Professionals who provide direct care to patients are considered as caregivers. (III) The PACU scale unavailable at data collection. (IV) Regarding the number of procedures performed in OR and PACU, considering that there was no contact between patients. (V) PACU/HD, Hemodynamics Post-

Anesthetic Recovery Service. (VI) Microorganisms observed/identified by sector during the length of stay: In the ward: *Acinetobacter baumannii* (MDR, Multidrug Resistant), *Candida sp*, *Stenotrophomonas maltophilia*; In the ICU: *Acinetobacter baumanii*, *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus saprophyticus*, *Staphylococcus haemolyticus*, *Staphylococcus epidermidis*, *Klebsiella pneumoniae*, *Serratia marcescens*, *Pseudomonas aeruginosa*.

Calculations were carried out related to values of prevalence, infectivity, and probability of infection. The number of contacts, susceptible patients and infected patients were considered to understand nodes and their possible interactions. In other words, connections that establish the edges of the complex network in sectors where cases of infection occurred (ICU and Ward). It was observed that the probability of the infection to occur was greater in the ward, probably due to the number of infected contacts having been greater, adjusted by length of stay (Table 3).

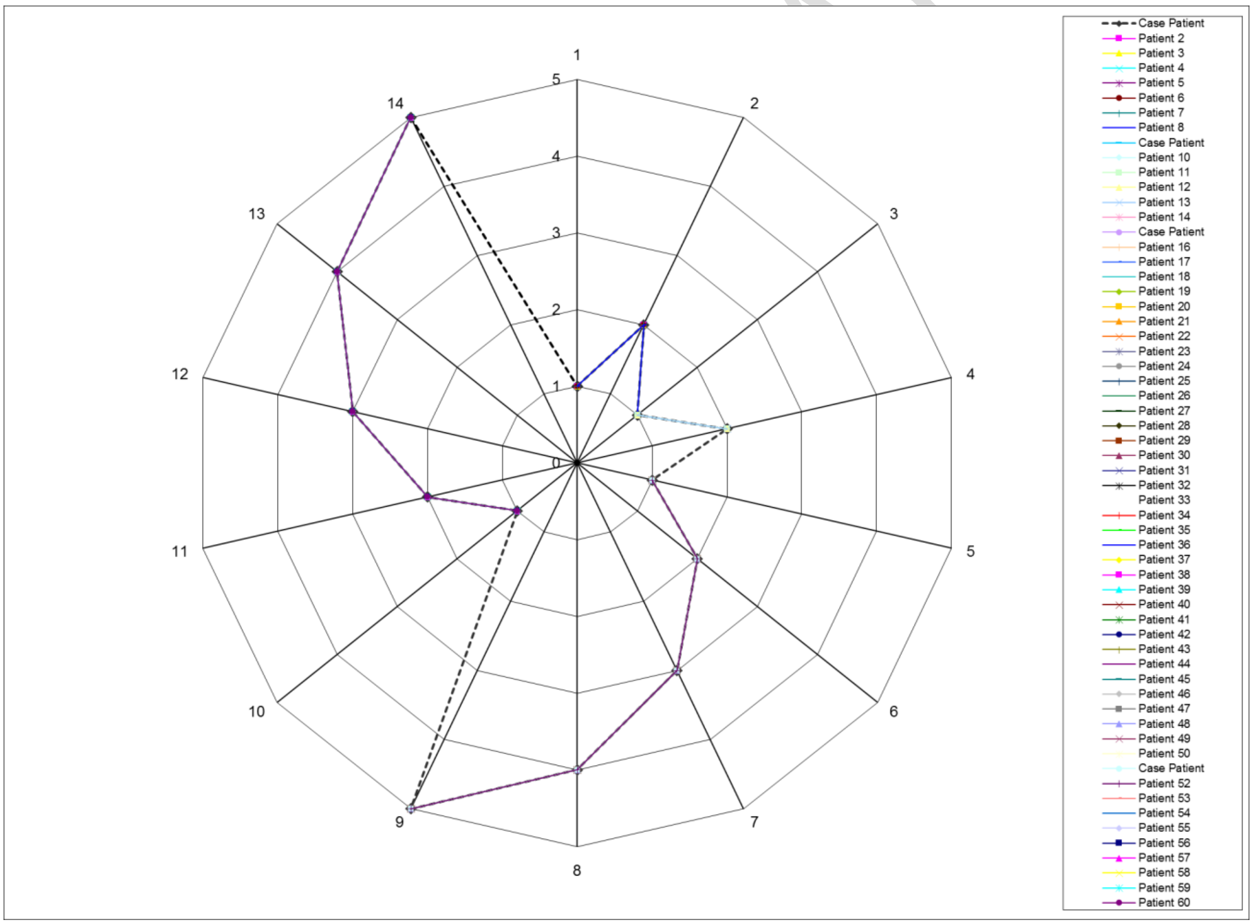
Table 3. Values of prevalence, infectivity, probability of infection, considering the number of contacts, susceptible and infected patients in relation to the case analyzed from April to July 2017, at HC/EBSERH/UFPE

		Sectors	
Standards	**Formulas**	**ICU**	**WAR.**
Contacts (C)[1]	Nº C	89	101
Susceptible (S)[2]	Nº S	12	40
Infected (I)[3]	Nº I	4	11
Prevalence of infection (π)	π=I/C	0. 04	0. 11
Infectivity (γ)	γ=I*S/C	0. 54	4. 36
Probability of infection (P)	P=1-(1-π*γ)C	0. 89	1. 00
Infected contacts (E)	E(Ci)=1/π*γ	12	40
Length of stay in days[4]	Td	28	70
Probability of infection adjusted for length of stay (Pq)	Pp=P*Td	24. 85	70. 00

Caption: Nº. = Number; ICU = Intensive Care Unit; WAR. = ward.
[1]Contacts is given by the number of beds occupied plus the number of admissions plus the number of caregivers in the sector (C).
[2]Susceptible is given by the number of beds occupied plus the number of admissions in the sector (S).
[3]Infected people is caused by the occurrence of infection/colonization by sector during the length of stay (I).
[4]Length of stay (LS) refers to the case under analysis, considering admissions in the sectors. Values are referenced in Table 2.

From the structuring elements of the complex network for this case, summarized in Tables 2 and 3, it was possible to model the graphs, i.e., the set of vertices and edges that are formed in the system.

Figure 1 shows the possibilities of contacts (nodes) with other patients and with the multidisciplinary team caregivers, considering a day of hospitalization. To this end, it was considered that 8 patients were in the operating room; in the PACU, 6 patients; in the ward, 36 patients; and in the ICU, 10 patients. Based on these scenarios, the schematic interaction network was modeled to illustrate the possibilities of contacts. Thus, in Figure 1, the various edges that form the web are observed, showing that caregivers, as well as other patients, can be sources of real dissemination within the system.



Caption: the numbers presented vertically, from 1 to 5, represent physicians (1), nurses (2), physiotherapists (3), nutritionists (4), and speech therapists (5). The "0" in the center represents only the web axis. The numbers surrounding the web represent the sum of these professionals in different sectors. Numbers 1 and 2 represent the operating room; 3 and 4 represent the PACU; 5 and 9 represent the ward; and 10 to 14 represent the ICU. For schematic assessment, a total of 60 patients were considered, including the case patient.

Figure 1. Sample of a network of possible interactions between the case assessed in the sectors where she was admitted and contacts from April to July 2017 at HC/EBSERH/UFPE

DISCUSSION

Individual tracing is an assessment method conducted during on-site studies, the purpose of which is to "trace" experiences of treatments, provision of services including real patients as a basis for assessing the level of adherence to standards. Tracing will lead to an assessment of quality, in which it is important to understand the concept of the seven dimensions applied to that specific context (effectiveness, effectiveness, efficiency, optimization, acceptability, legitimacy, and equity).[5]

To understand the factors that may have impacted the case and the outcome of death, this study started from analysis of all sectors and services involved until the understanding of the nodes and connections that form this complex network of interactions from tracer methodology, i.e., the case tracing. There was a high percentage of nonconformity in relation to the physical-functional structure of all sectors and services that provided care.

According to the study that analyzed 1,658 records in 3 hospitals, entitled *Características de EA em Hospitais do Rio de Janeiro* (freely translated as AE characteristics in Hospitals in Rio de Janeiro), the total avoidable AEs was 65, in which 7 out of 56 patients suffered more than one preventable AE. As for origin, the most frequent preventable AEs were related to surgery (32.3%) and non-surgical medical procedures (29.2%). The main preventable AEs were HAI (24.6%) and damage from surgical and/or anesthetic complications (20.0%). Of the 16 cases of HAI, 11 (68.7%) were due to SSI.[14] On the other hand, the frequency of SSI at *Hospital Sírio-Libanês,* São Paulo, between the last quarter of 2016 and 2017 was 0.89 %.[15]

Therefore, the impact that hospital administration and physical/functional structure can have on quality of care can be observed. It is believed that institutions should implement multimodal interventions, involving changing the organizational culture, to improve patient quality and safety and obtain promising results in accreditation programs. Accreditation, although voluntary, is considered to be a driving force for quality of care.

Indicators of structure (Level 1), process (Level 2) and result (Level 3) aim to guide and subsidize hospital management regarding implementing actions aimed at reducing incidence and severity of HAIs and measuring their effectiveness.

An indicator is not a direct measure of quality of care. Currently, it is a milestone that directs attention to certain specific results that should soon be the subject of a subsequent review, just as health security is not a value that can be measured exclusively by its results and repercussions. Its scope and benefits go beyond what we can measure with formal instruments. Its real nature of value lies in the effective ability to cause no damage, which is often not measurable.

When tracing data were aligned with analysis by complex networks, it was identified that SSI (graft removal in the left iliac) was more likely to have occurred in the ward (probability) both because this was the sector where the patient (case) remained for a longer time, as for the high number of contacts and also the presence of infected patients in this service.

By using the Barabási model for free-scale networks[16], it can be understood that networks present an order in the structuring dynamics, with very specific characteristics. One of the main characteristics, called preferential connection, is the tendency for a new vertex to connect to a network vertex that has a high degree of connections. Therefore, length of stay, in line with the number of possible, susceptible and infected contacts, leads to an understanding of the routes of SSI related to this case.

It should be noted that a network is basically described as a set of items, called vertices or nodes, which are connected to each other by edges.[17] It should be noted that complex networks form the backbone of complex systems. Each complex system, in this case, the Hospital, is a network of interactions between a large number of small elements. The concept of complex networks has been increasingly used in studies on the routes of disease transmission and evolution.[18] The transmission of microorganisms can occur when there is contact with the infected person, be it a patient, a caregiver or a hospital ward. [19]

Figure 2 shows a simple network, vertices joined by edges, from a cohort of two patients from the same ward. The nodes represent factors related to the patient, visitors and/or companions, the multidisciplinary team and support sectors. The edges interconnect patients forming a complex network in hospitals.

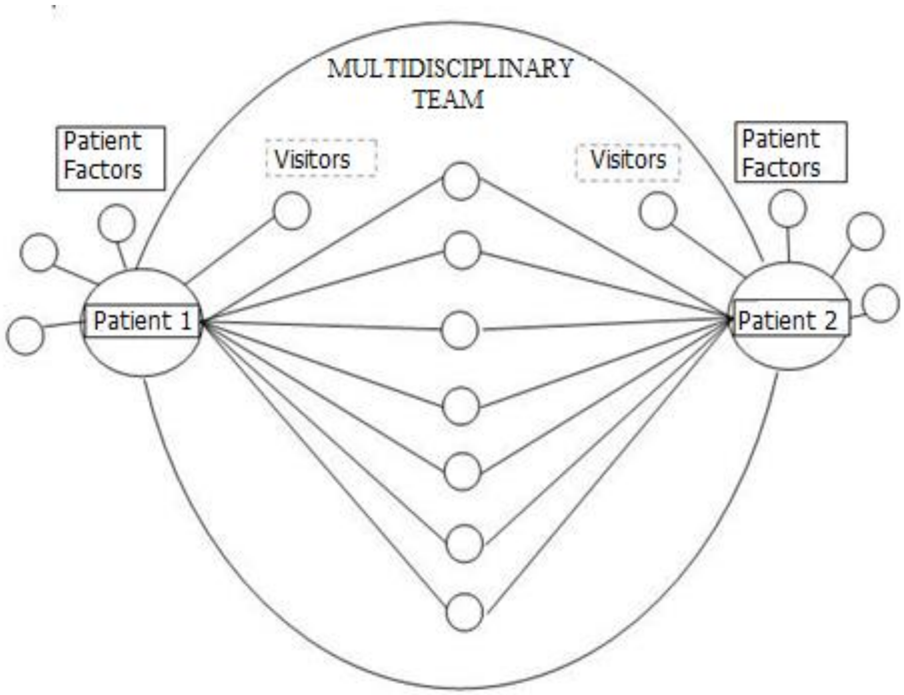


Figure 2. Complex ward network with two patients created by the author, based on the Barabási-Albert model[16]

Through this illustration, it is possible to predict the number of connections and interactions related to the case under study, which had a cohort of 167 patients (4 of whom were infected), plus 61 caregivers, for 41 days (time relative to the second admission) in one ward. In addition, only one sink for hand hygiene has been identified in this sector, which appears to be insufficient. It was also observed that the patient was in areas such as operating room, PACU and ICU, which increases the number of connections and interactions on the network.

Therefore, given the possible hypotheses for analysis of this case, it was observed that there is a greater chance of spreading the infection to be related to the set of contacts. Professionals are potential carriers of infections to susceptible patients in wards and ICUs. They are predictors of the spread of SSI (Scenario 2/Hypothesis 2) and/or the lack of structure for hand hygiene, as it promotes the spread of infection, so that physical structure, as can be seen in analysis by the tracer, does not contributed to best practice and favors the spread of infection from person to person (Scenario 3/Hypothesis 3).

Through this initial trial, it is already possible to observe the behavior of SSI progress and its potential for dissemination, with caregivers as a factor. Currently, the main problem is to carry out an analysis of the microbiological and genetic profile and the consequent relationship with the spread of microorganisms and occurrence of SSI. This type of analysis allows mapping this evolution based on institutional protocols of best practice in preventing HAIs. The complex network model allows identifying factors that trigger propagation, enabling safe care in hospitals.[20-22]

In the future, it is intended to apply other mathematical and statistical procedures to assess the association between the SSI rate (dependent variable) with the independent variables, based on the model established by Schweitzer et al.[22,23]

In conclusion, based on tracer methodology, aligned with analysis by complex networks, it is suggested that the forces that drive the HAI. In this case, especially SSI, they are probably related to caregivers and the physical-functional structure necessary for the development of health care.

It is feasible to understand that the responsibility for the event progression cannot be attributed to deficiency in physical and functional structure. Human behavior and professional attitudes can interfere in the process, but it is clear that quality starts with it. Due to the type of analysis, using the tracer tool, it is not possible to carry out an assessment with an individual and punitive focus, but on a systemic basis.

Multifactorial issues determine the structuring elements of a complex network in a hospital environment, in this case, represented by the fragility in the physical structure (probable inducing aspect) and functional, adjacent to professional skills.

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CONFLICTS OF INTEREST

The authors state that there were no conflicts of interest.

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