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Microbiological contamination of siphons in the neonatal intensive care unit of the Grenoble Alps university hospital and relationship with infections in premature infants

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MICROBIOLOGICAL CONTAMINATION OF SIPHONS IN THE NEONATAL INTENSIVE
CARE UNIT OF THE GRENOBLE ALPS UNIVERSITY HOSPITAL AND RELATIONSHIP
WITH INFECTIONS IN PREMATURE INFANTS

THÈSE

POUR LE DIPLÔME D'ÉTAT DE DOCTEUR EN MÉDECINE

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Le 04/10/2023

Par Mme Carola PIEROBON

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Titre : Contamination microbiologique des siphons du service de réanimation néonatale du CHU Grenoble-Alpes et relation avec les infections chez les prématurés

ABSTRACT FR

Introduction

Les siphons sont connus pour être des réservoirs de bacilles gram-négatifs depuis plusieurs décennies, mais le lien causal avec les infections des nouveau-nés et les voies de transmission n'ont pas été clairement établis.

Nous avons mené une étude avant/après visant à évaluer si la désinfection quotidienne des siphons réduisait le taux de contamination des siphons et le nombre d'infections nosocomiales des nouveau-nés dans l'unité de réanimation néonatale, en soins continus de néonatalogie et en médecine néonatale au CHU Grenoble Alpes.

Méthodes

Pour évaluer le taux de contamination des siphons, les prélèvements de siphons ont été inclus entre le 1er juin 2018 et le 30 juin 2022 (10 mois pour la période « avant » et 39 mois pour la période « après »). Pour évaluer les taux d'infections nosocomiales des nouveau-nés, la période d'inclusion était comprise entre le 1er janvier 2016 et le 30 juin 2022 (39 mois pour les deux périodes). Tous les échantillons cliniques positifs pour les bactéries gram-négatifs des patients admis dans l'un des trois services au cours de la période d'étude ont été inclus. Les infections communautaires et les infections néonatales bactériennes précoces ont été exclues.

Résultats

Au total, 115 prélèvements de siphon ont été inclus, soit 16,52 % (n=19) pour la période « avant » et 83,48 % (n=96) pour la période « après ». Le taux de contamination était de 78,95% pour la période « avant » et de 95,83% pour la période « après » (p=0,025). Nous avons identifié 232 microorganismes dans les siphons; 149 (64,22%) microorganismes étaient environnementaux, 82 (35,34%) étaient à la fois environnementaux et humains et un seul (0,43%), *Staphylococcus epidermidis*, était strictement humain. Au total, 223 microorganismes (96,12%) étaient pathogènes et 224 (96,55%) étaient des bactéries gram négatives. La distribution des

microorganismes était différente selon la période : 66,67% (n=24) étaient environnementaux et humains au cours de la période « avant » contre 29,59% (n=58) au cours de la période « après » ($p = 0,000021$).

Au cours de la période d'étude, 4030 hospitalisations ont eu lieu. Des prélèvements positifs ou cliniquement pertinents pour les bactéries gram négatives ont été identifiés pour 274 hospitalisations : 57 hospitalisations avec les mêmes gram négatifs identifiés dans les siphons et 137 hospitalisations avec d'autres gram négatif. Le taux d'infection aux mêmes microorganismes gram négatifs identifiés dans les siphons était de 1,06 dans la période « avant » et de 0,58 dans la période « après » par 1 000 jours-patients d'hospitalisation ($p = 0,023$) et de 2,02 dans la période « avant » et de 1,00 dans la période « après » pour 100 hospitalisations ($p = 0,008$). Aucune différence statistiquement significative n'a été retrouvée entre les taux d'infection pour l'ensemble des bactéries gram négatives entre les deux périodes.

Conclusions

Notre étude n'a pas démontré l'efficacité de la désinfection quotidienne des siphons pour réduire leur taux de contamination. Néanmoins, la désinfection pourrait avoir un effet de sélection sur les bactéries gram négatives en réduisant les bactéries d'origine environnementale et humaine. Plus important encore au cours de la période d'étude, le taux d'infection nosocomiale des nouveau-nés avec les mêmes gram négatif que ceux identifiés dans les siphons a diminué de moitié après la mise en œuvre de la désinfection. A la lumière de ces résultats, nous considérons qu'il est utile de poursuivre la désinfection quotidienne des siphons. L'échantillonnage systématique des siphons pourrait être arrêté et être restreint aux suspicions d'épidémie. Des études sont maintenant nécessaires pour déterminer le lien de causalité entre la contamination des siphons et les infections nosocomiales néonatales.

Title: Microbiological contamination of siphons in the neonatal intensive care unit of the Grenoble Alps University Hospital and relationship with infections in premature infants

ABSTRACT ENG

Introduction

Siphons have been known to be reservoirs of gram-negative bacilli for several decades but the causal link with infections of neonates and transmission pathways have not been firmly established.

We conducted a before-and-after study aimed to assess if the daily disinfection of siphons reduce the rate of contamination of siphons and the number of clinical nosocomial infections of neonates in the neonatal intensive care units, the neonatal continuous care unit, and the neonatal medicine at the Grenoble Alps University Hospital.

Methods

To assess rate of contamination of siphons, the samples of siphons were included between 1st June 2018 and 30 June 2022 (10 months in the «before» period and 39 months in the «after» period). To assess nosocomial infection rates of neonates, the inclusion period was between 1st January 2016 and 30 June 2022 (39 months for both periods). We considered every positive clinical samples for gram-negative organisms of patient admitted in one of three wards during the study period. Community-acquired infections and early bacterial neonatal infections were excluded.

Results

A total of 115 siphon samples were included, 16.52% (n=19) in the “before” period and 83.48% (n=96) in the “after” period. The rate of contamination was 78.95% in the “before” period and 95.83% in the “after” period (p=0.025). We identified 232 microorganisms in siphons; 149 (64.22%) microorganisms were environmental, 82 (35.34%) were both environmental and human and, only one (0.43%), *Staphylococcus epidermidis*, was strictly human. A total of 223 (96.12%) microorganisms were pathogenic and 224 (96.55%) were gram-negatives. The origin of microorganisms had a different distribution according to the period: 66.67% (n=24) were

environmental and human in the “before” period versus 29.59% (n=58) in the “after” period ($p=0.000021$).

During the study period, 4030 hospitalisations were recorded. A total of 274 hospitalizations had positive or clinically relevant samples for gram-negative bacteria: 57 hospitalizations with same gram-negative identified in siphons and 137 hospitalizations with others gram-negative. The rate of nosocomial infection to same gram-negative identified in siphons was 1.06 in the “before” period and 0.58 in the “after” period per 1000 patient-days of hospitalisation ($p=0.023$) and 2.02 in the “before” period and 1.00 in the “after” period per 100 hospitalizations ($p=0.008$). No statistically significant results were found in the comparison of global contamination rates for gram-negative bacteria between the two periods.

Conclusions

Our study has not demonstrated the effectiveness of siphon disinfection in reducing their contamination rate between the “before” and “after” period.

However, disinfection could have a selecting effect on gram-negative bacteria by reducing bacteria of environmental and human origin. Most importantly in the study period, the rate of neonates nosocomial infection to same gram-negative identified in siphons had significantly decreased by half after the implementation of disinfection. In the light of these results, we consider that it useful to continue the daily disinfection of siphons. Systematic siphon sampling could be stopped and sampling could be restricted in case of suspected outbreak. Further investigation is now necessary to determine the causal link between siphon contamination and neonates nosocomial infections.

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Introduction

According to the national survey conducted in 2017 by Santé Publique France (the French national public health institution), the prevalence of neonates with at least one nosocomial infection in neonatal intensive care units (NICUs) is 12.82% (1). The incidence of hospital-acquired (HA) sepsis is particularly high among neonates treated in NICUs compared to others ICUs. A systematic review included MEDLINE, Embase and the Global Index Medicus from January 2000 to March 2018 founded more than 110 out of 1000 admitted neonates suffered from HA sepsis, with HA neonatal sepsis representing more than 50% of all HA infections in study setting (2). In premature neonates under 1500 g, nosocomial infections are responsible for an overall excess mortality of more than 50% and 45% of deaths between 15 and 28 days (3).

Premature neonates combine endogenous and exogenous risk factors: the mechanical barrier of the skin and mucous membrane is extremely fragile in the large premature, the immune system is immature, and several risk factors are related to the hospital setting such as extended duration of central venous catheter (4).

Among the risk factors related to the hospital setting, we find the sink drainage systems. Siphons have been known to be reservoirs of gram-negative bacilli for several decades (5). The causal link and transmission pathways between gram-negative organisms contained in siphons and patient colonisation or infection have not been firmly established (6). Recently, a systematic review of the literature analysed sink drainage systems as reservoirs for HA Gammaproteobacteria colonization and infection (7). This review identified 52 articles, including 4 studies in NICU. To assess the quality of evidence for causality of sink drainage systems as reservoirs the modified CADDIS criteria (Causality Assessment of Sink Drains as a Reservoir for Hospital-Acquired Gammaproteobacterial Infection or Colonisations) have been applied. In details, these criteria include six domains of evidence: Spatial/Temporal Co-occurrence, Temporal Sequence, Stressor–Response Relationship, Causal Pathway, Evidence of Exposure and Biological Specificity, and Manipulation of Exposure. In this systematic review, no single study provided supporting evidence for all remaining Modified CADDIS domains.

Grenoble Alps University hospital (CHU GA) faced in September 2018, a cluster of three cases of *Enterobacter cloacae complex* conjunctivitis, including one death, in the NICU and neonatal medicine unit. Siphons were initially suspected as a potential source of the infection, considering the presence of the microorganism. However, further analysis of the strains failed to yield any definitive conclusions. In March 2019, after this episode and even if the causality link had not been proven, the Infection Control Unit of CHU GA decided to set up a daily disinfection of siphons with 20 mL of pure disinfectant detergent and steam flushing of siphons at patient discharge.

Hypothesis

We hypothesise that daily disinfection of siphons would reduce the rate of contamination of siphons and the number of clinical infections in neonates.

Objectives

The main objective of this study was to assess the rate of contamination of siphons in NICU, in neonatal continuous care unit, and the neonatal medicine unit of CHU GA before and after the implementation of the strategy (daily siphon disinfection).

The secondary objectives of the study were: assessing the rate of contamination of the siphons over time, describing the type of micro-organisms identified in the siphons and assessing infection rates of neonates with same gram-negative organisms identified in the siphons before and after the introduction of daily siphon disinfection.

Materials and Methods

Study design, setting and study period

The CHU GA is the reference university hospital of the Isère department (France) and serves a population of 675,000 inhabitants with 2,074 hospital beds and 375 places, and a total of 431 893 hospitalization days in 2022. The hospital in La Tronche hospital site has a level 3 neonatology service and registered 3810 births in 2022.

We conducted a before-and-after study in the NICU, the neonatal continuous care unit, and the neonatal medicine unit at the CHU GA. The study was carried out in 10-bed NICU, 8-bed neonatal continuous care unit and 8-bed neonatal medicine unit. Rooms could be single or double. We analysed the siphons of the sinks placed in the patients' rooms. Each room is equipped with a sink used in priority for hands washing of the healthcare workers.

To assess the rate of contamination of siphons the inclusion period last 4 years between 1 June 2018 and 30 June 2022. The “before” period took place from 1 June 2018 to 29 March 2019 (10 months) and the “after” period from 30 March 2019 to 30 June 2022 (39 months). To assess infection rates of neonates, the inclusion period last 6 years between 1st January 2016 and 30 June 2022. The “before” period took place from 1st January 2016 to 29 March 2019 (39 months) and the “after” period from 30 March 2019 to 30 June 2022 (39 months).

Microorganisms found in siphons and in neonates samples have been classified according to their natural environment (human, environmental or both) and their pathogenicity. The pathogenicity of bacteria was determined in accordance with the scientific literature (8) and according to the recommendations of the biology department of CHU GA.

Outcomes definition

The primary outcome was the rate of contamination of the siphons, expressed as a percentage. A siphon was contaminated if an organism was identified, regardless of its pathogenicity. Samples were considered compliant if no microorganisms were identified.

The first secondary outcome was the rate of contamination of the siphons over time expressed as a percentage. The compliance of siphon sampling over time was reported on semesters. The "before" period consisted of two semesters (VI: April 2018 to September 2018 and VII: October 2018 to March 2019). The "after" period was divided into seven semesters (VIII: April 2019 to September 2019, IX: October 2019 to March 2020, X: April 2020 to September 2020, XI: October 2020 to March 2021, XII: April 2021 to September 2021, XIII: October 2021 to March 2022, XIV: April 2022 to September 2022). It must be pointed out that the first and last semesters are not complete: in the semester "April 2018- September 2018" samples started in June 2018 and in the semester "April 2022- September 2022" samples finished in June 2022.

The second secondary outcome was the description of microorganisms identified grouped by class according to their origin (human or environmental or both) and their pathogenicity (pathogenic or non-pathogenic).

The third secondary outcome was the infection rate of neonates with gram-negative organisms and the infection rate of neonates with same gram-negative bacteria identified in the siphons expressed per 100 hospitalizations and per 1000 patient-days of hospitalization. The "before" period consisted of seven semesters (I: January 2016 to March 2016, II: April 2016 to September 2016, III: October 2016 to March 2017, IV: April 2017 to September 2017, V: October 2017 to March 2018, VI: April 2018 to September 2018 and VII: October 2018 to March 2019). The "after" period was divided into seven semesters (VIII: April 2019 to September 2019, IX: October 2019 to March 2020, X: April 2020 to September 2020, XI: October 2020 to March 2021, XII: April 2021 to September 2021, XIII: October 2021 to March 2022, XIV: April 2022 to September 2022). It must be pointed out that the first and last semesters are not complete: we considered neonatal clinical samples from January 2016 to March 2016 for the first semester and from April 2022 to June 2022 for the last semester.

Study population

A systematic sampling of siphons was implemented in the neonatology department of the CHU GA since June 2018. Each siphon was sampled twice a year in the NICU and once a year in the neonatal continuous care and neonatal medicine units. From 29 March 2019, siphons were daily

disinfected using 20 mL disinfectant detergent or diluted Oxy'floor during winter gastroenteritis outbreaks. Siphons were systematically disinfected with a steam device after patient discharge for the three neonatal wards. Siphons were replaced once every semester in NICU, in neonatal continuous care unit, and in neonatal medicine since 2009. Traceability of replacement of siphons was introduced in 2020. There was therefore no traceability for previous years.

Every patient admitted in one of these three wards, during the study period, with a positive clinical sample for gram-negative organisms, was eligible to be included in the study. All nosocomial infections in neonates in the NICU, neonatal continuous care unit and neonatal medicine unit of the CHU GA were included in the analysis. Only clinical samples were considered. Samples for screening were not considered. A nosocomial infection was defined as any infection occurred in children born in the CHU GA or more than two days after his admission. Early bacterial neonatal infections, defined as infections developed straight after birth and transmitted by the mother, were excluded from the analysis. We excluded early bacterial neonatal infections certain or probable based on the patient's medical record.

Collected variables

Siphons sampling

A trained technician from the infection control unit of CHU GA carried out siphon sampling. The equipment used for each sampling consisted of a sterile 60 mL syringe, a sterile suction probe and a sterile bottle. Sampling was carried out dipping the suction probe into the siphon, avoiding touching the metal part at the bottom of the washbasin, then the probe was inserted until the bottom of the siphon (the probe cannot go any lower). Using the syringe, the liquid was aspirated and emptied into the sterile bottle. The aspiration was repeated several times until the siphon was empty. For biological analysis of the siphon samples, 100 µL of the sample were inoculated onto one Drigalski agar, one ANC agar and one blood agar. Bacteria were identified using a MALDI-TOF mass spectrometer. The technicians identified colonies suggestive of gram-negative bacilli, colonies showing beta-haemolysis (suggestive of *Staphylococcus aureus*), colonies suggestive of enterococci and colonies most represented.

Neonates' information

Demographic information, such as age and sex, were gathered for each patient from the informatics patient register. The information collected included birth weight, gestational age expressed in amenorrhea weeks (AW; extremely preterm if ≤ 27 AW, very preterm if ≥ 28 AW et ≤ 31 AW, moderate to late preterm if ≥ 32 AW et ≤ 36 AW) (9), biological markers of infection like C-reactive protein (CRP), presence and type of invasive medical devices (deep catheter and intubation), hospital average length of stay and rate of mortality.

Statistical analyses

We presented the quantitative variables with their median and interquartile ranges (IQR) and then compared those using non-parametric tests. For qualitative variables, we presented them with number and percentages and used the Chi² test or Fisher's exact test to compare them. The evolution of the infection rate per 100 hospitalizations and per 1000 patient-days of hospitalisation, as a function of the siphon contamination rate, was observed through trend curves for the before and after periods. The statistical significance p value threshold for our analysis was 0.05. These statistical analyses were carried out using STATA version 17.0.

Ethics

The database was declared to the CHU GA Data Protection Officer. The study was authorised by the local clinical research department on 24 March 2023.

Results

Primary outcome

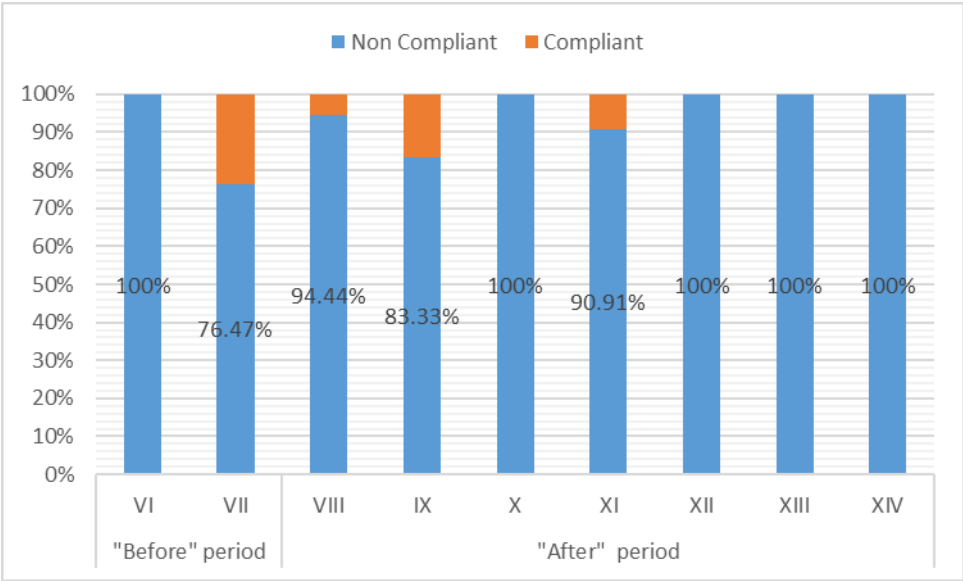
During the study period, 115 siphon samples were taken: 19 (16.52%) samples were made in the “before” period and 96 (83.48%) sample in the “after” period. The global rate of contamination of siphons was 93.04%, 107 samples were non-compliant. The rate of contamination was 78.95% in the “before” period and 95.83% in the “after” period ($p=0.025$). A total of 69 (60.00 %) samples was taken in NICU, 27 (23.48%) in neonatal continuous care unit and 19 (16.52%) the neonatal medicine unit. In NICU, 13 (18.84%) samples were made in the “before” period and 56 (81.16%) in the “after” period. The global rate of contamination of siphons in NICU was 95.65%, 66 samples were non-compliant. The rate of contamination in NICU was 84.62% in the “before” period and 98.21% in the after period ($p=0.089$).

Secondary outcomes

First secondary outcome

We presented the rate of siphon contamination over time by semesters in figure 1.

Figure 1. Frequency and conformity of sampling according to the study period



A smaller number of samples were made in the “before” period. To note, there was a peak of compliant samples in the semester “October 2018 – March 2019”: actions of disinfection and siphon replacement took place in the same period following the cluster of three cases of *Enterobacter cloacae complex* conjunctivitis in the NICU and neonatal medicine unit. We notice that five out of nine semesters were non-compliant at all.

Second secondary outcome

We identified 232 microorganisms in siphons during the study period. They belonged to 25 species: the most represented were *Achromobacter species* (25.43%), *Serratia marcescens* (19.40%) and *Pseudomonas aeruginosa* (13.36%)

The frequency of findings of microorganisms is described in the table 1.

Table 1. Frequency and rate of identification of microorganisms in siphons during the study period

Microorganisms	Frequency of identification of microorganisms	Rate of identification of microorganisms
<i>Achromobacter denitrificans</i>	1	0.43%
<i>Achromobacter sp.</i>	59	25.43%
<i>Achromobacter xylosoxidans</i>	1	0.43%
<i>Acinetobacter junii</i>	1	0.43%
<i>Acidovorax temperans</i>	1	0.43%
<i>Aeromonas species</i>	1	0.43%
<i>Bacillus circulans</i>	1	0.43%
<i>Burkholderia cepacia</i>	12	5.17%
<i>Burkholderia species</i>	2	0.86%
<i>Citrobacter freundii</i>	5	2.16%
<i>Enterobacter cloacae</i>	20	8.62%
Environmental flora	4	1.72%
<i>Herbaspirillum species</i>	4	1.72%
<i>Klebsiella oxytoca</i>	2	0.86%
<i>Klebsiella pneumoniae</i>	8	3.45%
<i>Moraxella osloensis</i>	1	0.43%
<i>Mycoplasma</i>	1	0.43%
<i>Pseudomonas aeruginosa</i>	31	13.36%
<i>Pseudomonas mosselii</i>	6	2.59%
<i>Pseudomonas putida</i>	1	0.43%
<i>Pseudomonas sp.</i>	13	5.60%
<i>Serratia marcescens</i>	45	19.40%
<i>Staphylococcus epidermidis</i>	1	0.43%
<i>Stenotrophomonas maltophilia</i>	10	4.31%
<i>Streptomyces species</i>	1	0.43%

According to their origin, 149 (64.22%) microorganisms were environmental, 82 (35.34%) were both environmental and human and, only one (0.43%), *Staphylococcus epidermidis*, was strictly human. According to their pathogenicity, 223 (96.12%) microorganisms were pathogenic and 9 (3.88%) were non-pathogenic. Among the samples made, 224 (96.55%) microorganisms were gram negatives. Most microorganisms are pathogenic and gram negative in both study periods. The origin of microorganisms has a different distribution according to the period: in the “before” period, 33.33% (n=12) of microorganisms were environmental and 66.67% (n=24) were environmental and human. In the “after” period, 69.90% (n=137) were environmental and

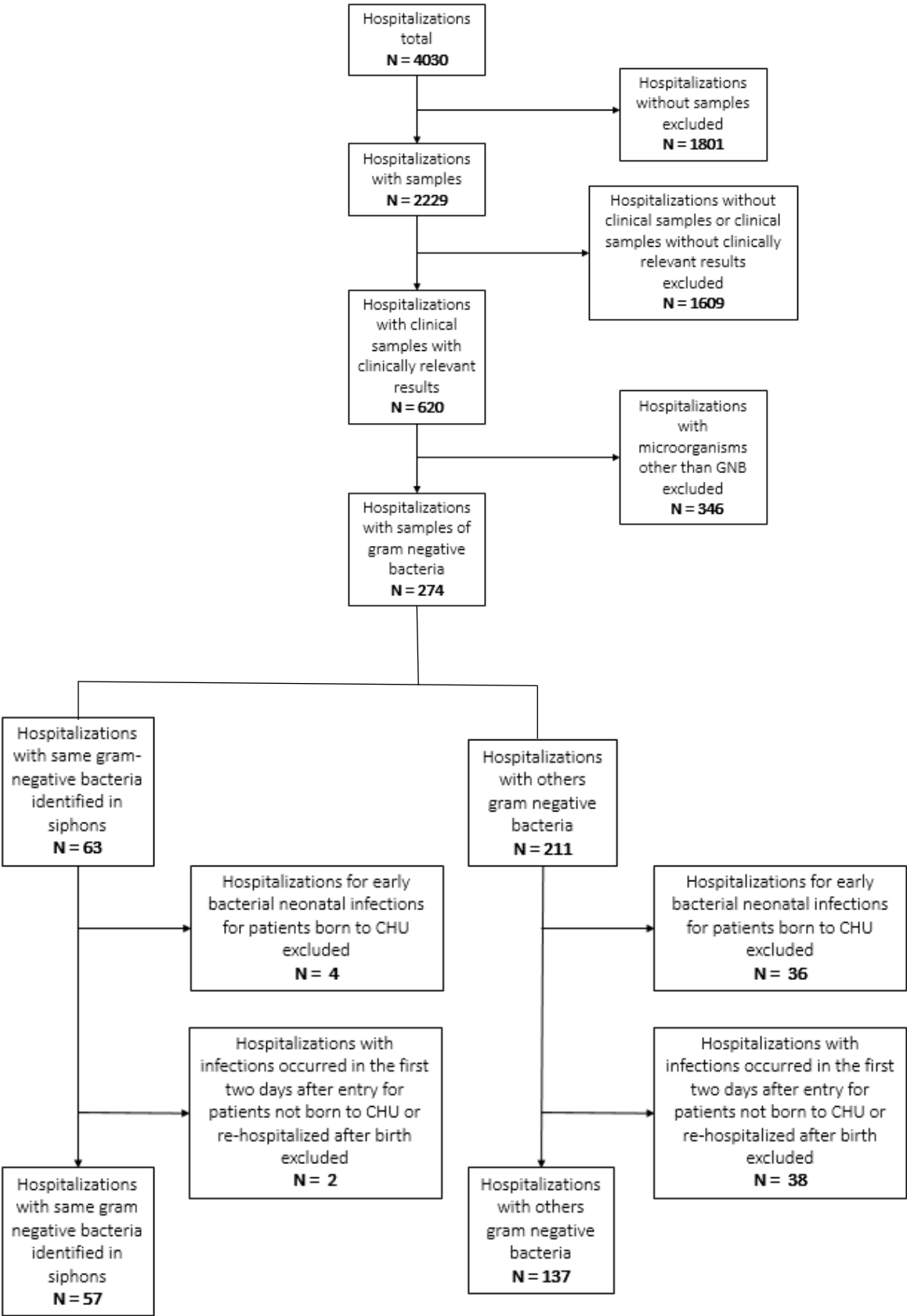
29.59% (n=58) were environmental and human (p=0.000021). The classification of microorganisms according to their origin, their pathogenicity and their status gram negative is described in Appendix 1.

Third secondary outcome

During the study period, 9728 samples of neonates were taken. We have only considered clinical samples (n=5726); the most frequent were blood culture (29.44%), respiratory specimens (15.46%) and gastric fluid (14.51%). The classification of neonate's samples according to their type is described in Appendix 2. Among the clinical samples, after exclusion of samples that are negative, sterile or with a threshold value not clinically relevant, a total of 2910 samples have been found. Among these samples, 503 were positive for gram-negative bacteria and, of these, 121 were founded in the siphons.

A total of 4030 hospitalisations was recorded during the study period: the samples were realized for 2229 of these hospitalizations. Among these, 620 hospitalizations had a clinical sample with a positive or clinically relevant result. The study focused on the sampling of gram-negative bacteria: 274 hospitalizations met the criteria, 63 hospitalizations with same gram-negative identified in siphons and 211 hospitalizations with others gram-negative. Among these, we excluded hospitalizations for early bacterial neonatal infections for patients born at the CHU (n=40) and hospitalizations with infections occurred in the first two days after entry for patients not born to CHU or re-hospitalized after birth (n=40): we identified 57 hospitalizations with same gram-negative identified in siphons and 137 hospitalizations with others gram-negative (figure 2).

Figure 2. Flow-chart of hospitalization's selection

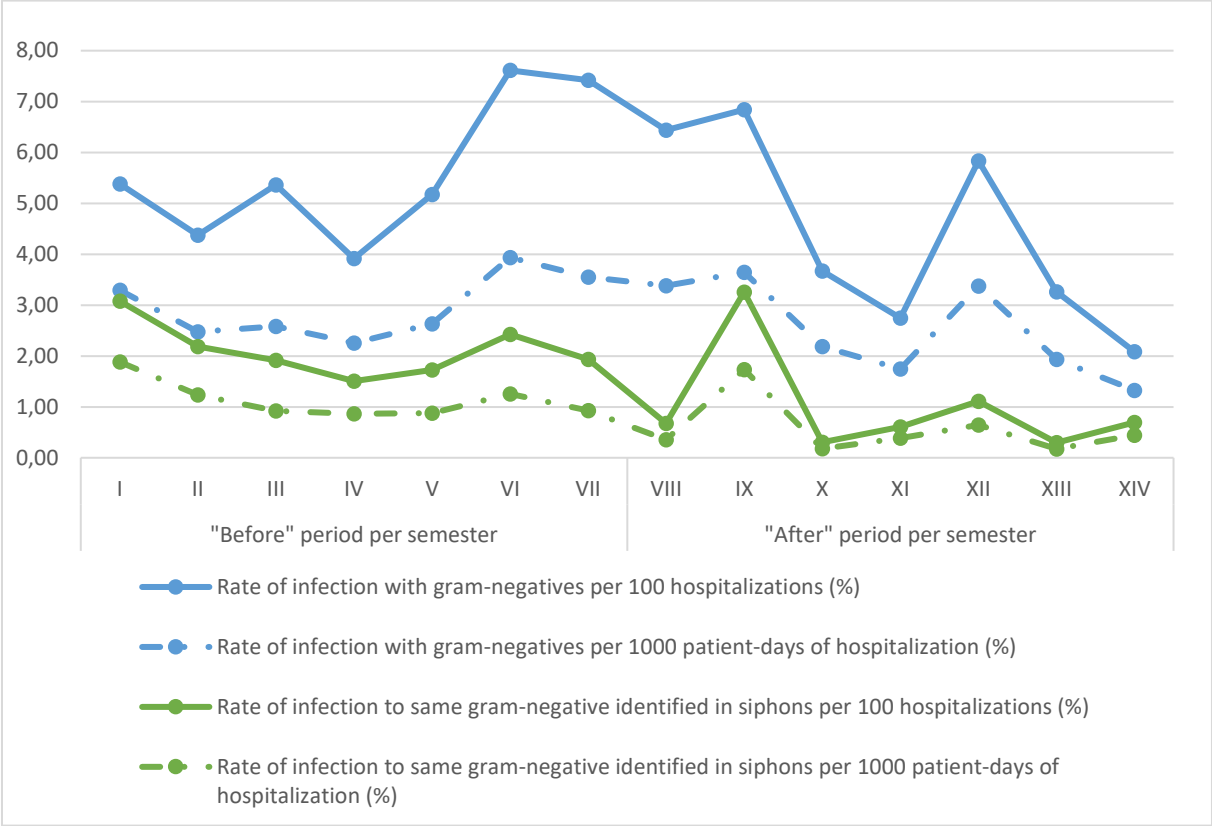


We have identified a total of 204 infections with gram-negatives: 108 in the “before” period and 96 in the “after” period. Eight patients had multiple infections, five in the “before” period and four in the “after” period. The rate of infection with gram-negatives per 1000 patient-days of hospitalization was 2.94 in the “before” period and 2.65 in the “after” period ($p=0.46$). The rate of infection with gram-negatives per 100 hospitalization was 5.59 in the “before” period and 4.58 in the “after” period ($p= 0.16$).

Among the hospitalizations in the study, we have identified 60 infections with same gram-negative identified in siphons: 39 in the “before” period and 21 in the “after” period. Two patients had multiple infections in the “before” period and none in the “after” one. The rate of infection to same gram-negative identified in siphons per 1000 patient-days of hospitalisation was 1.06 in the “before” period and 0.58 in the “after” period ($p=0.023$). The rate of infection to same gram-negative identified in siphons per 100 hospitalization was 2.02 in the “before” period and 1.00 in the “after” period ($p=0.008$).

These infection rates are represented per semester in figure 3. The rate of infection between the “before” period and the “after” period both infections with gram-negatives and infection to same gram-negative identified in siphons seemed to decreased. The lower infection rates for infections with gram-negatives were recorded in the “after” period, especially in the semester XI and XIV. The lower infection rates for infection to same gram-negative identified in siphons were also recorded in the “after” period, especially in the semester VIII, X and XIII.

Figure 3. Rates of infection to same gram-negative bacteria identified in siphons and with gram-negatives bacteria per semester



Characteristics of the population included in the 57 hospitalizations with infections to same gram-negative identified in siphons were described in the table 2. The population affected by infections with gram-negative bacteria found in siphons was composed mostly of extremely preterm neonates (29.82%); the median of the birth weight was 1290 gr. A total of 31 (54.39%) neonates had invasive medical dispositive: in details, 29 (50.88%) had deep catheters and 15 (26.32%) were intubated. C-reactive protein was lower than 10 mg/L for 18 (31.58%) neonates, higher than 10 mg/L for 23 (40.35%) patients and was not measured for 16 (28.07%) patients. Three most frequent clinical samples were eye samples, urine samples and respiratory specimens for both periods. Their global rate was 30.00% for eye samples, 21.43% for urines samples and 20.00% for respiratory specimens. The median hospital average length of stay is 76 days. The global mortality rate was 8.77% (n=5). No statistically significant difference in gestational age, median birth weight, presence of medical invasive devices, CRP, hospital average length of stay, three most frequent types of clinical samples and mortality rate was found between

patients in the “before” and “after” period. The most frequent organisms identified in the neonates clinical samples were *Klebsiella pneumonia* (48.72%), *Pseudomonas aeruginosa* (20.51%) and *Enterobacter cloacae* (17.95) in the “before” period and *Klebsiella pneumonia* (42.86%), *Klebsiella oxytoca* (23.81%) and *Serratia marcescens* (19.05%) in the “after” period.

Table 2. Characteristics of the 57 hospitalizations with infections to same gram-negative identified in siphons

	Study period	Before period	After period	p value
Hospitalisations	57	36	21	
Sex				
Male	30	20	10	
Female	27	16	11	
Gestational age (in AW)				0.13
< 27 AW	17 (29.82%)	8 (22.22%)	9 (25.00%)	
> 28 AW et < 31 AW	16 (28.07%)	9 (25.00%)	7 (19.44%)	
> 32 AW et < 36 AW	10 (17.54%)	9 (25.00%)	1(2.78%)	
> 37 AW	14 (24.56%)	10 (27.78%)	4 (11.11%)	
Median birth weight with IQR (in grams)	1290 [840 – 2530]	1435 [897,5-2912,5]	1080 [740 – 1430]	0.08
Invasive medical devices (presence)				
Total	31 (54.39%)	20 (55.56%)	11 (52.38%)	0.81
Deep catheter	29 (50.88%)	19 (52.78%)	10 (47.62%)	
Intubation	15 (26.32%)	9 (25.00%)	6 (28.57%)	
CRP	N= 41	N= 28	N= 13	0.63
< 10 mg/L	18 (43.90%)	13 (46.43%)	5 (38.46%)	
> 10 mg/L	23 (56.10%)	15 (53.57%)	8 (61.54%)	
Type of clinical samples (the three most frequent)				0.65
Eye samples	21 (30.00%)	13 (28.26%)	8 (33.33%)	
Urine samples	15 (21.43%)	8 (17.39%)	7 (29.17%)	
Respiratory specimens	14 (20.00%)	10 (21.74%)	4 (16.67%)	
Hospital average length of stay with IQR (in days)	76 [28 – 102]	55.5 [25-94]	95 [31 – 124]	0.13
Mortality rate	5 (8.77%)	4 (11.12%)	1 (4.76%)	0.64

AW: amenorrhea week; IQR: interquartile ranges; CRP: C-reactive protein

Discussion

Our protocol of siphon disinfection did not reduce their contamination rate between the “before” and “after” period, and led to a contrary effect. Despite this, disinfection could have a selecting effect on gram-negative bacteria by reducing bacteria of environmental and human origin. Moreover, the rate of neonates’ infection to same gram-negative identified in siphons per 1000 patient-days of hospitalisation and per 100 hospitalizations has significantly decreased by half after the implementation of disinfection.

In our study, we found a very high overall siphon contamination rate of 93.04%. We conducted a study in a non-outbreak period and included all types of bacteria found in siphons. It is complex to compare the rate of siphons’ contamination of our study to literature data since most studies are carried out during an outbreak or for a specific type of microorganism. In a review of 23 carbapenem-resistant organism outbreaks, the level of sink contamination with outbreak strain organisms ranged widely from 16% to 100% (10). In the first extensive multicentre regional study to document handwashing sink contamination in a non-outbreak context in France, the rate of contamination was high, more than 30% but the study was focused only on Extended-spectrum beta-lactamase-producing Enterobacteriaceae (ESBL-E) and carbapenemase-producing Enterobacteriaceae (CPE) (11). From our results, most of the germs found in the siphons were gram negatives (96.55%). Gram-negative bacteria were described to persist longer than gram-positive bacteria and many gram-negative species can survive on inanimate surfaces even for several months (12). According to these findings and given the fact that it has been identified only once, we consider the *Staphylococcus epidermidis* identified as a probable contamination of the sample.

Our protocol of siphon disinfection did not reduce their contamination rate between the “before” and “after” period and led to an opposite effect (78.95% vs 95.83%, $p=0.025$). This result must be interpreted with cautious considering that most of the samples of the siphons were made following the disinfection protocol and that siphon disinfection and replacement strategies were implemented during a cluster of *Enterobacter cloacae complex* at September 2018.

The effectiveness of disinfection of siphons in reducing their contamination rate in literature is heterogeneous. Any attempts at sink sterilisation were futile in the study conducted by Kotsans

et al. (13) and daily bleach protocols being ineffective in nine reports of Carling's review of carbapenem-resistant organism outbreaks (10). In Lowe et al. study, thrice-daily protocol of disinfection decreased sink colonisation from 16.4% to 3.9% and an reduction in protocol compliance resulted in the sink colonization rate returning to 16.7% (14). In the Roux et al. study, routine use of a disinfectant made no significant contribution to preventing sink contamination but daily use of bleach appeared to be the most effective approach to limiting ESBL-E contamination of sink drains with all siphons ESBL-E free ($p < 0.001$) (11). From literature data, it seems that the daily disinfection of siphons is effective at least against some types of bacteria. These data support a selection effect on microorganisms and could explain the transition from presence of environmental and human microorganisms before the protocol to presence of microorganisms of only environmental origin after the introduction of disinfection.

Literature should be interpreted in the light of the frequency of application of the protocols (weekly, daily or several times a day) and the different disinfectant products used; Carling's review protocol disinfection found ineffective a phenolic disinfectant, an acetic acid protocol, a glucoprotamin protocol and the addition of a vaporized hydrogen peroxide system protocol to other intervention (10).

Our results should be analyzed taking into account the replacement of siphons that is carried out twice a year in the three wards. In the examined literature, two studies applied siphon substitution: the strategy was evaluated partially effective or not evaluated (10). A third study considers the replacement of siphons an efficient but temporary solution. Washing hands and discarding of wash water will bring new bacteria into the siphon and a new biofilm will be formed (15). Other measures taken to remove biofilm from all sink associated to daily use of bleach solution seems efficient in the Chapuis study (16).

We acknowledge that our identification results may be partial due to the technology used for identification. In a study conducted at CHU GA in 2022, biofilms were recovered from the siphons of 26 patient rooms in the neonatal ward. The bacterial diversity identified by culture was low with nine different bacterial species in the hospital waste water biofilm while preliminary analysis of the full-length 16S rRNA sequencing data of 11 sink biofilm samples identified more than 100 different species (17).

Regarding the link between siphon contamination and infections, two systematic reviews have investigated the role of sink drainage systems as reservoir for HA colonization and infection, one for gamma-proteobacteria colonization and infection and one for carbapenem-resistant organisms (CRO) colonization and infection. Outbreaks of carbapenem-resistant organisms were found more commonly in ICUs and immunocompromised patients, the review suggests that acquisition of infection from sink drains may be more widespread in in-patients (7) (18). In the Kizny's review there was evidence of CRO transmission between the environment and patients based on phenotypic or genotypic methods in all studies assessing this. Despite this, transmission routes were difficult to characterize, possibly due to both limited sampling and typing resolution (18).

In NICU, the prevalence of nosocomial infections is high (19) and higher than the nosocomial infections of other departments (2). Low birthweight, premature birth, underlying disease, common antimicrobial use and invasive practices are risk factors for nosocomial infections (20). All these factors are frequent features of neonates hospitalized in NICU. Only one article of Volling's review (7) set in NICU reported the clinical characteristics of neonates. In this study, risk factors as prematurity, Apgar score superior to 5 at one minute and at five minutes, total parenteral nutrition and medical invasive device, in particular central venous catheter, Levine tube and umbilical catheter, were looked for. Total parenteral nutrition administration emerged as the sole statistically significant risk factor for *Serratia marcescens* carriage or infection (21). A causal link between neonates' infections and siphon contamination was not found in this study. Despite this, during third outbreak analysed, a type VIII *Serratia marcescens* strain, the prevalent clinical clone during this period, was detected in the milk kitchen sink drain. In our study, we have not identified significant difference in the clinical characteristics of neonates infected to same gram negative bacilli identified in the siphons between the "before" and "after" period. Furthermore, we have not collected the clinical characteristics of neonates non-infected or infected with other gram negative bacilli in our study.

We found that the rate of nosocomial infection of neonates to same gram-negative identified in siphons decreased after the implementation of the disinfection protocol. Also the overall rate of nosocomial infections to gram negative bacteria seemed to decrease but was not statistically significant. The most important limit of our study to the interpretation of these results is analysis of causal link between siphon contamination and neonatal infections. In their systematic review,

Volling et al. used six criteria, the Modified CADDIS tool, to assess the quality of evidence that Gammaproteobacteria in sink drainage systems represent a reservoir for colonization or infection of patients or healthcare workers in acute care hospitals. Each modified CADDIS domain was necessary but not sufficient to assess causality. None of the 52 studies analysed provided supporting evidence for all these criteria. The first criteria was the spatial or temporal co-occurrence of contaminated sink drainage systems and organism acquisition. In our setting a spatial co-occurrence was possible since sinks are located directly within the neonate's room. Further investigations are necessary to determine the temporal co-occurrence of the same bacterium in siphons and in patient samples. Secondly, a temporal sequence must be demonstrated. Our study has not collected exhaustive data to determine if the siphon was contaminated before the patient was infected. The third criteria is the stressor/response relationship: we cannot establish the duration of exposure and the degree of contamination of siphons was not analysed in our microbiological investigations. No study presented clear evidence about stressor/response relationship in the systematic review. A causal pathway must be proven in the modified CADDIS criteria. In our study, we can exclude some pathways analysed in the systematic review as direct patient use of sinks with contaminated drains, in addition, the use of sinks should be restricted to the handwashing of healthcare workers. . Other more frequent pathways must be analyzed, especially, contamination of healthcare personnel hands or gowns during use of sinks with contaminated drains, and subsequent transmission to patients and splash, aerosolization, or leak of bacteria from contaminated sink drains onto surroundings. These pathways were hypothesized 24 and 19 times respectively in the systematic review but demonstrated only in 5 and 11 studies. Adequately discriminatory typing methods to identify if the organism cultured from siphons and colonized patients were the same or closely related must be utilized. This type of analysis were not provided in our protocol, may be carried out in further prospective studies. The last modified CADDIS criteria was the manipulation of exposure. We realized three manipulation on siphons: daily disinfection, use of a steam device after patient discharge and siphons replacement. Our investigations have not demonstrated the effectiveness of the strategy on siphons (7).

Our study does have some limitations. We did not demonstrated the causal link between the contaminated siphons and neonates infections. However, a reduction of neonates' infection rate to same gram negative bacteria identified in the siphons was established. We have not

identified difference in clinical characteristic of patients infected to same gram negative bacteria identified in siphons. However, it might be interesting to analyse other data that could not be collected for this study. In particular, it might be useful to know antibiotic therapy of neonates. During our study, in January 2021, protocol of risk management of early neonatal bacterial infection has changed for neonates born after 34 AW at CHU GA. Furthermore, collecting clinical data and risk factor of all hospitalized neonates to compare if differences exist between neonates with infection to same gram-negative identified in siphons and neonates with infection to other gram-negative bacteria could had interesting information. Others methods of analysis than the culture of the siphon collections could be to used to exhaustively identify the bacteria present in the siphons. Moreover, this study remains a monocentric retrospective study with all limitations related.

Conclusion

Our study has not demonstrated the effectiveness of siphon disinfection in reducing their contamination rate between the “before” and “after” period. This result should take into account the lower number of samples collected in the “before” period. The effectiveness of disinfection of siphons in reducing their contamination rate in literature is heterogeneous: while in some studies disinfection was found to be ineffective, in others the contamination rate was reduced but only for some types of microorganisms. In our study, we showed that disinfection could have a selecting effect on gram-negative bacteria by reducing bacteria of environmental and human origin. Most importantly in the study period, the rate of neonates nosocomial infection to same gram-negative identified in siphons has significantly decreased by half after the implementation of disinfection. In the light of these results, we consider that it useful to continue the daily disinfection of siphons. Systematic siphon sampling could be stopped and sampling could be restricted in case of suspected outbreak. Further investigation is now necessary to determine the causal link between siphon contamination and neonate’s nosocomial infections.

THÈSE SOUTENUE PAR : Carola PIEROBON

TITRE :

Microbiological contamination of siphons in the neonatal intensive care unit of the Grenoble Alps University Hospital and relationship with infections in premature neonates

CONCLUSION :

Siphons have been known to be reservoirs of gram-negative bacilli for several decades but the causal link with infections of neonates and transmission pathways have not been firmly established. We conducted a before-and-after study aimed to assess if the daily disinfection of siphons reduce the rate of contamination of siphons and the number of clinical infections of neonates in the neonatal intensive care unit, the neonatal continuous care unit, and the neonatal medicine at the Grenoble Alps University hospital.

The samples of siphons were included between 1st June 2018 and 30 June 2022 (10 months in the «before» period and 39 months in the «after» period). To assess infection rates of neonates, the inclusion period was between 1st January 2016 and 30 June 2022 (39 months for both periods). We considered every positive clinical samples for gram-negative organisms of patient admitted in one of three wards during the study period. Community-acquired infections and early bacterial neonatal infections were excluded.

A total of 115 siphon samples were taken, 16.52% (n=19) in the "before" period and 83.48% (n=96) in the "after" period. The rate of contamination was 78.95% in the "before" period and 95.83% in the "after" period (p=0.025). We identified 232 microorganisms in siphons; according to their origin, 149 (64.22%) microorganisms were environmental, 82 (35.34%) were both environmental and human and, only one (0.43%), *Staphylococcus epidermidis*, was strictly human. A total of 223 (96.12%) microorganisms were pathogenic and 224 (96.55%) were gram-negatives. The origin of microorganisms has a different distribution according to the period: 66.67% (n=24) were environmental and human in the "before" period versus 29.59% (n=58) in the "after" period (p=0.000021). During the study period, 4030 hospitalisations were recorded. A total of 274 hospitalizations had positive or clinically relevant samples for gram-negative bacteria: 57 hospitalizations with same gram-negative identified in siphons and 137 hospitalizations with others gram-negative. The rate of infection to same gram-negative identified in siphons was 1.06 in the "before" period and 0.58 in the "after" period per 1000 patient-days of hospitalisation (p=0.023) and 2.02 in the "before" period and 1.00 in the "after" period per 100 hospitalizations (p=0.008). No statistically significant results were found in the comparison of global contamination rates for gram-negative bacteria between the two periods.

Our study has not demonstrated the effectiveness of siphon disinfection in reducing their contamination rate between the "before" and "after" period (78.95% vs 95.83%, p=0.025). This result should take into account the lower number of samples collected in the "before" period. The effectiveness of disinfection of siphons in reducing their contamination rate in literature is heterogeneous: in some studies disinfection was found to be ineffective, in others the contamination rate was reduced but only for some types of microorganisms.

Disinfection could have a selecting effect on gram-negative bacteria by reducing bacteria of environmental and human origin (66.67% vs 29.59%, p=0.000021).

Most importantly in the study period, the rate of neonates infection to same gram-negative identified in siphons has significantly decreased (rate of infection to same gram-negative identified in siphons per 1000 patient-days of hospitalisation in the "before" and "after" period was 1.06 vs 0.58, p=0.023) after the implementation of disinfection. In the light of these results, we consider that it useful to continue the daily disinfection of siphons. Systematic siphon sampling could be stopped and sampling could be restricted in case of suspected outbreak. Further investigation is now necessary to determine the causal link between siphon contamination and neonates infections.

VU ET PERMIS D'IMPRIMER

Grenoble, le : 14/09/23

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Bibliography

1. Santé publique France, Enquête nationale de prévalence des infections nosocomiales et des traitements anti-infectieux en établissements de santé, mai-juin 2017. Saint-Maurice : Santé publique France, 2019. 270 p. Disponible à partir de l'URL : www.santepubliquefrance.fr.
2. Markwart R, Saito H, Harder T, Tomczyk S, Cassini A, Fleischmann-Struzek C, et al. Epidemiology and burden of sepsis acquired in hospitals and intensive care units: a systematic review and meta-analysis. *Intensive Care Med*. 2020 Aug;46(8):1536–51.
3. Stoll BJ, Hansen N, Fanaroff AA, Wright LL, Carlo WA, Ehrenkranz RA, et al. Late-Onset Sepsis in Very Low Birth Weight Neonates: The Experience of the NICHD Neonatal Research Network. *Pediatrics*. 2002 Aug 1;110(2):285–91.
4. Doit C, Biran V, Aujard Y. Infections nosocomiales en néonatalogie. In: *Infections néonatales* [Internet]. Elsevier; 2015 [cited 2023 Jul 16]. p. 91–106. Available from: <https://linkinghub.elsevier.com/retrieve/pii/B9782294741357000097>
5. Levin MH, Olson B, Nathan C, Kabins SA, Weinstein RA. Pseudomonas in the sinks in an intensive care unit: relation to patients. *J Clin Pathol*. 1984 Apr 1;37(4):424–7.
6. Snitkin ES. Contamination of Hospital Plumbing: A Source or a Sink for Antibiotic-Resistant Organisms? *JAMA Netw Open*. 2019 Feb 15;2(2):e187660.
7. Volling C, Ahangari N, Bartoszko JJ, Coleman BL, Garcia-Jeldes F, Jamal AJ, et al. Are Sink Drainage Systems a Reservoir for Hospital-Acquired Gammaproteobacteria Colonization and Infection? A Systematic Review. *Open Forum Infect Dis*. 2021 Feb 1;8(2):ofaa590.
8. Rémic: référentiel en microbiologie médicale. 7e édition, 2022. Paris: Société française de microbiologie; 2022.
9. World Health Organization, WHO recommendations for care of the preterm or low-birth-weight infant. Geneva: World Health Organization; 2022.
10. Carling PC. Wastewater drains: epidemiology and interventions in 23 carbapenem-resistant organism outbreaks. *Infect Control Hosp Epidemiol*. 2018 Aug;39(8):972–9.
11. Roux D, Aubier B, Cochard H, Quentin R, Van Der Mee-Marquet N. Contaminated sinks in intensive care units: an underestimated source of extended-spectrum beta-lactamase-producing Enterobacteriaceae in the patient environment. *J Hosp Infect*. 2013 Oct;85(2):106–11.
12. Pantel A, Richaud-Morel B, Cazaban M, Bouziges N, Sotto A, Lavigne JP. Environmental persistence of OXA-48–producing *Klebsiella pneumoniae* in a French intensive care unit. *Am J Infect Control*. 2016 Mar;44(3):366–8.
13. Kotsanas D, Wijesooriya WRPLI, Korman TM, Gillespie EE, Wright L, Snook K, et al. “Down the drain”: carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. *Med J Aust*. 2013 Mar;198(5):267–9.
14. Lowe C, Willey B, O’Shaughnessy A, Lee W, Lum M, Pike K, et al. Outbreak of Extended-Spectrum β -Lactamase–producing *Klebsiella oxytoca* Infections Associated with Contaminated Handwashing Sinks. *Emerg Infect Dis*. 2012 Aug;18(8):1242–7.

15. Wolf I, Bergervoet PWM, Sebens FW, Van Den Oever HLA, Savelkoul PHM, Van Der Zwet WC. The sink as a correctable source of extended-spectrum β -lactamase contamination for patients in the intensive care unit. *J Hosp Infect*. 2014 Jun;87(2):126–30.
16. Chapuis A, Amoureux L, Bador J, Gavalas A, Siebor E, Chrétien ML, et al. Outbreak of Extended-Spectrum Beta-Lactamase Producing *Enterobacter cloacae* with High MICs of Quaternary Ammonium Compounds in a Hematology Ward Associated with Contaminated Sinks. *Front Microbiol* [Internet]. 2016 Jul 12 [cited 2023 Sep 5];7. Available from: <http://journal.frontiersin.org/Article/10.3389/fmicb.2016.01070/abstract>
17. Hennebique A, Landelle C, Terreaux-Masson C, Maurin M, Mercier C, Bülow E. Monitoring antibiotic resistant pathogens in hospitals by metagenomic characterization of sink and hospital wastewater biofilms in comparison with conventional culturing methods. Poster. 33rd European Congress of Clinical Microbiology and Infectious Diseases, 2023, Copenhagen, Denmark;
18. Kizny Gordon AE, Mathers AJ, Cheong EYL, Gottlieb T, Kotay S, Walker AS, et al. The Hospital Water Environment as a Reservoir for Carbapenem-Resistant Organisms Causing Hospital-Acquired Infections—A Systematic Review of the Literature. *Clin Infect Dis*. 2017 May 15;64(10):1435–44.
19. Sohn AH, Garrett DO, Sinkowitz-Cochran RL, Grohskopf LA, Levine GL, Stover BH, et al. Prevalence of nosocomial infections in neonatal intensive care unit patients: Results from the first national point-prevalence survey. *J Pediatr*. 2001 Dec;139(6):821–7.
20. Moffa M, Guo W, Li T, Cronk R, Abebe LS, Bartram J. A systematic review of nosocomial waterborne infections in neonates and mothers. *Int J Hyg Environ Health*. 2017 Nov;220(8):1199–206.
21. Maltezou HC, Tryfinopoulou K, Katerelos P, Ftika L, Pappa O, Tseroni M, et al. Consecutive *Serratia marcescens* multiclonal outbreaks in a neonatal intensive care unit. *Am J Infect Control*. 2012 Sep;40(7):637–42.

Appendix

Appendix 1. Classification of microorganisms according to their origin, their pathogenicity and status gram negative

Microorganism	Origin	Pathogenicity	Gram negative bacteria
<i>Achromobacter denitrificans</i>	Environmental	Pathogenic	Yes
<i>Achromobacter sp.</i>	Environmental	Pathogenic	Yes
<i>Achromobacter xylosoxidans</i>	Environmental	Pathogenic	Yes
<i>Acinetobacter junii</i>	Environmental	Pathogenic	Yes
<i>Acidovorax temperans</i>	Environmental	Non pathogenic	Yes
<i>Aeromonas species</i>	Environmental	Pathogenic	Yes
<i>Bacillus circulans</i>	Environmental	Pathogenic	Non
<i>Burkholderia cepacia</i>	Environmental	Pathogenic	Yes
<i>Burkholderia species</i>	Environmental	Pathogenic	Yes
<i>Citrobacter freundii</i>	Environmental and human	Pathogenic	Yes
<i>Enterobacter cloacae</i>	Environmental and human	Pathogenic	Yes
<i>Environmental flora</i>	Environmental	Non pathogenic	Non
<i>Herbaspirillum species</i>	Environmental	Non pathogenic	Yes
<i>Klebsiella oxytoca</i>	Environmental and human	Pathogenic	Yes
<i>Klebsiella pneumoniae</i>	Environmental and human	Pathogenic	Yes
<i>Moraxella osloensis</i>	Environmental and human	Pathogenic	Yes
<i>Mycoplasma</i>	Environmental and human	Pathogenic	Non
<i>Pseudomonas aeruginosa</i>	Environmental	Pathogenic	Yes
<i>Pseudomonas mosselii</i>	Environmental	Pathogenic	Yes
<i>Pseudomonas putida</i>	Environmental	Pathogenic	Yes
<i>Pseudomonas sp.</i>	Environmental	Pathogenic	Yes
<i>Serratia marcescens</i>	Environmental and human	Pathogenic	Yes
<i>Staphylococcus epidermidis</i>	Human	Pathogenic	Non
<i>Stenotrophomonas maltophilia</i>	Environmental	Pathogenic	Yes
<i>Streptomyces species</i>	Environmental	Pathogenic	Non

Appendix 2. Classification of neonate's clinical samples according to their type

Type of neonate's clinical samples	Frequency of neonate's clinical samples	Rate of neonate's clinical samples
Blood cultures	1686	29.44%
Respiratory specimens	885	15.46%
Gastric fluid	831	14.51%
Eye samples	573	10.01%
Urine samples	553	9.66%
Cerebrospinal fluid	454	7.93%
Skin samples	211	3.68%
Stools	144	2.51%
Liquids	139	2.43%
Vascular catheters	123	2.15%
Others types	50	0.87%
Dialysis fluid	47	0.82%
Abscess	16	0.28%
Equipment	14	0.24%
Total	5726	100.00%

Appendix 3. Table of articles

Author, review, year of publication	Type of study	Country	Period of time	Bacteria	Hospital setting	Hypothetical source of contamination	Outcomes	Results
Carling P et al, Infection Control & Hospital Epidemiology, 2018	Literature review (23 studies)	Europe, Australia, USA	PubMed database from 1990 to 2018	Carbapenem-resistant organism (CRO): <i>Pseudomonas aeruginosa</i> (n=9) <i>Klebsiella pneumoniae</i> (n=3) <i>Escherichia coli</i> (n=3) <i>Klebsiella oxytoca</i> (n=3) <i>Serratia species</i> (n=1)	Intensive care units (n=23)	Waste water drains, Sink	Clarify the clinical relevance of clusters associated with wastewater drain pathogen transmission during outbreaks	Level of sink colonization with outbreak strain organisms ranged widely (16%-100%). Daily bleach protocols were ineffective in 9 reports. One study noted that increasing the daily bleach disinfection protocol to three times daily reduced the presence of CRO. Replacement of several siphons was planned but not evaluated.
Chapuis A et al, Frontiers in Microbiology, 2016	Monocenter before and after study	France (Dijon)	January 2011 - December 2013	Extended-Spectrum Beta-Lactamase Producing <i>Enterobacter cloacae</i> (ESBL-E)	Hematology ward	Patients sink drain, Patients shower drain, Medical sink drains	Description of a large outbreak of ESBL-producing <i>E. cloacae</i> . Evaluation of the bleach disinfection programme implemented in December 2012 after the mechanical removal of biofilm in all sink.	Detection of 17 ESBL-producing <i>E. cloacae</i> in patient and medical sink. Six pulsotypes were identical between clinical and environmental isolates. Substantial fall in cases number of infection after the implementation of the disinfection, only three new cases occurred between January and May 2013. Settle drains accessible to achieve correct cleaning as well as to use disinfectant with proved activity against nosocomial pathogens.

Author, review, year of publication	Type of study	Country	Period of time	Bacteria	Hospital setting	Hypothetical source of contamination	Outcomes	Results
Clarivet B et al, Eurosurveillance, 2016	Monocenter study	France (Montpellier)	November 2012 - February 2014	OXA-48-producing <i>Klebsiella pneumoniae</i>	Intensive care units (n=7)	Siphons, Sink	Investigate epidemiological links between Kp OXA-48 positive patients with no evident epidemiological source of transmission	Despite the daily chlorination process, the epidemic clone was identified from siphons of sink in room occupied by a Kp OXA-48-colonised patient (n=2). The direction of contamination can be questioned and it was not possible to determine the origin of the environmental strain. Indirect arguments in favor of a sink-to-patient contamination : patients had prior negative MDRO screening before their stay in this room. No further case acquired in hospital has been identified after the corrective works on incriminated water outlet.
Hennebique A et al, ECCMID, 2023	Monocenter study	France (Grenoble)	2022	Antibiotic resistant bacteria	Neonatal ward (n=1)	Siphons patient room	Implemented culture and culture-independent approaches to assess hospital sink biofilms and wastewater biofilms as potential sources of antibiotic resistant bacteria accumulation and transmission	No ARBs were identified by culture. The bacterial diversity was low, with an average of 3 different bacterial species identified per sink, and 11 and 9 different bacterial species in the hospital WW and WW biofilm, respectively. Preliminary analysis of the full-length 16S rRNA sequencing data of 11 sink biofilm samples identified more than 100 different species across the samples. A high diversity of ARGs and MGEs in all biofilm samples was detected, amongst them carbapenemases and ESBL genes.
Kizny Gordon A et al, Clinical Infectious Diseases, 2017	Systematic review of the literature (32 studies)	Europe (n=16), Asia (n=7), North America (n=6) Australia (n=3)	PubMed from 1967 to 2016	Carbapenem-resistant organisms (CRO)	Medical/surgical wards, Intensive care units	Drains, Sinks, Faucets, Water/tea dispenser, Toilet bowl/brush	Summarize studies identifying common CROs in the hospital water environment, the evidence for CRO transmission between this environment and patients, and successful interventions to terminate outbreaks and eliminate CROs from this environment	Standardizing patient and environmental screening, and microbiological methods, when investigating CRO outbreaks may allow earlier detection of reservoirs. A combination of interventions is probably required to terminate outbreaks and eradicate CROs from the environment. Useful approaches include reinforcing general infection control measures combined with chemical disinfection using hydrogen peroxide vapor. Replacement and improved management of colonized water reservoirs is also probably an important component of control.

Author, review, year of publication	Type of study	Country	Period of time	Bacteria	Hospital setting	Hypothetical source of contamination	Outcomes	Results
KotsanasD et al, The Medical Journal of Australia, 2013	Monocenter study	Australia (Melbourne)	November 2009 - July 2012 (patients) September 2012 - October 2012 (sinks)	Carbapenem resistant Enterobacteriaceae (CRE)	Intensive care unit (n=1)	Sinks, Taps, Drains, Water fountains, Ice machines	Highlights the key role of bacterial environmental contamination and sink design in the propagation of CRE outbreaks	Molecular methods establish clonality between clinical and environmental isolates. CRE growth after one week after cleaning of grates and drains using single-use soft brushes in addition to hypochlorite deep cleaning and after three days after cleaning using pressurised steam decontamination. Sink design did not comply with Australasian clinical design standards and handwashing sinks had been used incorrectly.
LevinMH et al, Journal of Clinical Pathology, 1984	Monocenter prospective study	USA (Chicago)	1984 (six weeks)	<i>Pseudomonas aeruginosa</i>	Intensive care unit (n=1)	Sink drain	To better understand the acquisition of <i>P. aeruginosa</i> , potential environmental sources had been extensively cultured. In particular, a detailed study of sinks was included.	All 11 sinks analysed contained multiple strains of <i>P. aeruginosa</i> : some strains persisted for weeks while others were isolated once. The sequence of recovery of phenotypically similar isolates suggested that sinks were the source of at most two acquisitions of <i>P. aeruginosa</i> by patients.
LoweC et al, Emerging Infectious Diseases, 2012	Monocenter study	Canada (Toronto)	October 2006 – March 2011	Extended-spectrum beta-lactamase producing <i>Klebsiella oxytoca</i> (ESBL-E)	Intensive care units (n=1) Step-down units (n=1) Cardiac care unit (n=1)	Handwashing sinks	Description of investigation of the source of the <i>K. oxytoca</i> outbreak, and the interventions implemented to contain the outbreak.	No infections occurred after implementation of sink cleaning three times-day, sink drain modifications, and an antimicrobial stewardship program.

Author, review, year of publication	Type of study	Country	Period of time	Bacteria	Hospital setting	Hypothetical source of contamination	Outcomes	Results
MaltezouH et al, American Journal of Infection Control, 2012	Unmatched case-control study	Greece (Athens)	December 2007 - September 2010	<i>Serratia marcescens</i>	Neonatal intensive care unit (n=1)	Sink drain, Incubators, TPN solutions, Milk formulas, powder and bottles	Identify risk factors for <i>Serratia marcescens</i> infection	No association between a positive <i>Serratia marcescens</i> culture and the most part of factors was demonstrated. The only factor statistically significant was total parental nutrition (during outbreak 3, a type VIII <i>S. marcescens</i> strain, the prevalent clinical clone during this period, was detected in the milk kitchen sink drain).
MarkwartR et al, Intensive Care Med, 2020	Systematic review and meta-analysis (51 studies)	Europe, America, Asia (22 low and middle income countries)	MEDLINE, Embase et the Global Index Medicus from January 2000 to March 2018	Not specified	Intensive care units (n=28) Neonatal intensive care units (n=13) Others wards (n=10)	Not specified	Summarize the epidemiological evidence related to the burden of hospital acquired (HA) and ICU-acquired sepsis	Incidence rate of nosocomial infections in NICU is 112.9 cases per 1000 patients. In NICUs, 56.6% of HAIs were found to be HA neonatal sepsis. No study provided data on the mortality of neonates in NICUs with HA neonatal sepsis.
MoffaM et al, International Journal of Hygiene and Environmental Health, 2017	Systematic review of the literature (25 studies)	17 Countries (13 with high incomes)	PubMed, Web of Science, Embase, and clinicaltrials.gov. from 1951 to 2016	12 types of bacteria. The most frequent: <i>Pseudomonas aeruginosa</i> <i>Flavobacterium meningosepticum</i> <i>Klebsiella pneumoniae</i>	Neonatal ward	Tap water, Wash basin siphons and showers, Water for preparing solutions, Water for ventilation systems and for incubators	Target the main water sources and transmission routes as risk factors for nosocomial infections	The most common sources of contaminated water are taps and siphons. Most other possible sources were not contaminated. Low birthweight, premature birth, underlying disease, common antimicrobial use and invasive practices are risk factors for nosocomial infections.

Author, review, year of publication	Type of study	Country	Period of time	Bacteria	Hospital setting	Hypothetical source of contamination	Outcomes	Results
PantelA et al, American Journal of Infection Control, 2015	Monocenter study	France (Nimes)	June 2012 - March 2014	OXA-48-producing <i>Klebsiella pneumoniae</i>	Intensive care unit (n=1)	Sink drains, Ventilation system, Barriers of beds, Soap holders, Respirators	Description of epidemiological characteristics of the OXA-48-producing <i>Klebsiella pneumoniae</i> outbreak	Persistence of OXA-48-producing <i>K. pneumoniae</i> in the same hospital room for 20 months (sink drains and mattress, n=2/15). After mattress remove and change of sinks, environmental screening leading to negative results. Microbiological tests showed that 5 clinical and 2 environmental strains were all OXA-48-producing <i>K. pneumoniae</i> .
RouxD et al, Journal of Hospital Infection, 2013	Multicenter study	France	January 2013	Beta-lactamase-producing Enterobacteriaceae (ESBL-E) : <i>Klebsiella spp.</i> (n=33) <i>Enterobacter spp.</i> (n=18)	Intensive care units (n=13)	Handwashing sink dedicated to healthcare worker, Room patient sink	Assess if handwashing sinks in 135 ICU patient rooms are a potential source of contamination and identify factors associated with an increased risk of sink contamination	The contamination rate of sink drains varied from 0 to 81.8% of the samples. A lower ESBL-E sink contamination rate is associated to use of the sink restricted to handwashing (7/52 vs 24/72, p=0.034), sink disinfection with bleach as compared to that with quaternary ammonium compounds (0/19 vs 20/56, p=0.002) and daily sink disinfection using bleach as compared to weekly disinfection with bleach (0/19 vs 9/20, p<0.001).
VollingC et al, Open Forum Infectious Diseases, 2020	Systematic review (52 studies)	20 countries	MEDLINE, EMBASE, CINAHL, Cochrane, Aqualine, Scopus, BIOSIS and Web of Science from 1959 to 2014	Gammaproteobacteria : <i>Pseudomonas aeruginosa</i> (n=31) <i>Klebsiella pneumoniae</i> (n=7)	Intensive care units (n=31) Other wards	Sink drainage system	Assess the quality of evidence of transmission from sink drainage systems as reservoirs of nosocomial Gammaproteobacteria infections using the Modified CADDIS Tool	No single study provided supporting evidence for all remaining Modified CADDIS domains. As each domain is necessary but not sufficient to assess causality, this limits the overall causality assessment.
Wolff et al, Journal of Hospital Infection, 2014	Monocenter prospective study	Netherlands	December 2010 - April 2012	Extended-Spectrum Beta-Lactamase Producing Enterobacteriaceae (ESBL-E)	Intensive care unit (n=1)	Sink	Investigate whether patients in intensive care unit could have been colonized by ESBL-E originating from the sinks in patient rooms. Evaluation if self-disinfecting siphon could be an effective intervention to prevent future transmissions of ESBL-E.	ESBL-E were isolated from all 13 sinks. Four patients became colonized with ESBL-E that were genetically identical to ESBL-E that had previously been isolated from the sink. Transmission from sinks to patients was stopped by integrating self-disinfecting siphons to all sinks on the ICU.

Le serment d'Hippocrate

Texte revu par l'Ordre des médecins en 2012

“ Au moment d'être admis(e) à exercer la médecine, je promets et je jure d'être fidèle aux lois de l'honneur et de la probité.

Mon premier souci sera de rétablir, de préserver ou de promouvoir la santé dans tous ses éléments, physiques et mentaux, individuels et sociaux.

Je respecterai toutes les personnes, leur autonomie et leur volonté, sans aucune discrimination selon leur état ou leurs convictions. J'interviendrai pour les protéger si elles sont affaiblies, vulnérables ou menacées dans leur intégrité ou leur dignité. Même sous la contrainte, je ne ferai pas usage de mes connaissances contre les lois de l'humanité.

J'informerai les patients des décisions envisagées, de leurs raisons et de leurs conséquences.

Je ne tromperai jamais leur confiance et n'exploiterai pas le pouvoir hérité des circonstances pour forcer les consciences.

Je donnerai mes soins à l'indigent et à quiconque me les demandera. Je ne me laisserai pas influencer par la soif du gain ou la recherche de la gloire.

Admis(e) dans l'intimité des personnes, je tairai les secrets qui me seront confiés. Reçu(e) à l'intérieur des maisons, je respecterai les secrets des foyers et ma conduite ne servira pas à corrompre les mœurs.

Je ferai tout pour soulager les souffrances. Je ne prolongerai pas abusivement les agonies. Je ne provoquerai jamais la mort délibérément.

Je préserverai l'indépendance nécessaire à l'accomplissement de ma mission. Je n'entreprendrai rien qui dépasse mes compétences. Je les entretiendrai et les perfectionnerai pour assurer au mieux les services qui me seront demandés.

J'apporterai mon aide à mes confrères ainsi qu'à leurs familles dans l'adversité. Que les hommes et mes confrères m'accordent leur estime si je suis fidèle à mes promesses ; que je sois déshonoré(e) et méprisé(e) si j'y manque. ”