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Controlling Risks in the Compounding Process of Individually Formulated Parenteral Nutrition: Use of the FMECA Method (Failure modes, effects, and Criticality Analysis)

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Abstract: Parenteral nutrition (PN) in the neonatal intensive care unit (NICU) involves a succession of risky processes. The objective was to identify and prioritize the risks associated with PN in order to improve the quality of the pathway. A failure modes, effects, and criticality analysis (FMECA) was used to identify potential PN pathway failure modes. A multidisciplinary working group conducted a functional analysis of the processes, then listed the failure modes (FM). The FM criticality was assessed on a scale from 1 to 5 for occurrence (O), severity (S), and detection (D). The risk priority number (RPN), ranging from 1 to 125, was calculated. The FMECA identified 99 FM (prescription (n = 28), preparation (n = 48), and administration (n = 23)). The median RPN was 12, with scores ranging from 3 to 48. 25 % of the scores had an RPN > 21.75.

Among them, 12 were associated with prescription FM, 5 were associated with FM related to preparation and 8 were associated with a FM linked to administration. It allowed us to prioritize areas of potential quality improvement for parenteral nutrition of the preterm infant. The results demonstrated the need for the presence of a clinical pharmacist in the NICU to ensure the quality of PN process.

Keywords: nutrition, healthcare quality, pediatrics, infusion, prescribing

Introduction

Preterm infants are highly vulnerable to malnutrition. The energy intake necessary to ensure their growth is very high during this period (45–120 kcal/kg/day according to the post-natal age) [1, 2]. Enteral nutrition through breast milk should be preferred when the digestive tract is functional, improving preterm infant growth and reducing adverse events related to central catheter lines [1]. When the gastrointestinal tract is dysfunctional or inaccessible (cannot initiate enteral nutrition, necrotizing enterocolitis, gastrostomy), parenteral nutrition (PN) is used. PN formulations are complex admixtures that consist of multiple components, including both macronutrients (amino acids, lipids and dextrose) and micronutrients (electrolytes, vitamins, and trace elements) [3]. The importance of nutritional support for preterm neonatal outcomes is becoming increasingly accepted [4]. The quality and quantity of daily nutritional intake is critical, particularly during the first weeks of life, since amino acid, energy, and lipid intake from parenteral nutrition (PN) have been shown to be associated with later development [5]. Despite the emergence of standardized industrial nutrient solutions for the pediatric population in 2010, hospital pharmacies are sometimes required to prepare individually formulated PN for infants specifically adapted to their needs. In 2013, after the death of 3 infants under PN, national recommendations from the French Department of Health presented national guidelines for managing risks related to PN activity in neonatal intensive care units (NICU) through the implementation of good organizational practices [6, 7]. The PN pathway is a complex combination of high-risk activities. It involves various persons (physicians, pharmacists, pharmacy technicians, nurses) in various geographical locations (NICU, pharmacy) which increase the risk of adverse events and medication errors. Several studies have recently identified some risks associated with the PN pathway [8, 9]. In 2016, Mackay et al. identified 230 drug errors per 84,503 PN prescriptions in a pediatric hospital in the United States (2.7 errors per 1,000 PN) [8]. The main failure modes (FM) identified was the lack of electronic prescription and its transcription for preparation [8]. These 2 risks are present in our establishment.

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Indeed, the prescription of parenteral nutrition is not computerized and there is a step of re-transcription of the prescription at the pharmacy during the preparation of PN.

In our hospital, about 5,000 in-hospital preparations of PN are produced each year, mainly for the neonatal and pediatric intensive care units, but also for oncology patients and post-surgery. Thus, many newborn infants are exposed to a theoretical risk of adverse events: risks related to the prescription, the transmission, the possible re-transcriptions, and the conditions of administration to children, besides risks related to the preparation process [10]. We analyzed eight reports of adverse events related to PN over the years 2017 and 2018 in our institution. They consisted of 6 incidents related to identity vigilance errors and 2 to delivery issues (late delivery or sent to the wrong department).

The aim of the study was to carry out a risk analysis of the whole parenteral nutrition process using a failure modes, effects, and criticality analysis (FMECA) method and select action priorities to improve quality based on results.

Materials and methods

Setting

The analysis was conducted from March 2018 to August 2018 in a university hospital with a pediatric intensive care unit and a parenteral compounding unit.

Overview of the process

Prescriptions for PN were carried out daily between 8:00am and 12:30pm by the physician in the NICU in accordance with international guidelines (ESPGHAN) [1]. Taken into account are the clinical condition of the patient, including the weight; biological laboratory assessment, nutritional needs; postnatal age, and constraints related to pharmacy compounding. Prescriptions were written in a spreadsheet (Excel, Microsoft, United States) and were converted directly to a volume of adequate, specially adapted formula (e.g. the dosage of amino acids were directly converted to an adequate amount of commercial amino acid intravenous solution for the weight of the patient) in order to establish a prescription.

The prescriptions were transmitted by fax to the pharmacy before 12:30pm, 7 days per week. The pharmacist checked the admissibility (patient identity, date of prescription, osmolarity concordance/route of administration), and the validity (biological balance checked) of the prescription,

then the PN was prepared using an automated compounding device (Medimix®, IMF, Germany) located inside an ISO class 5 pharmaceutical isolator with positive air pressure (Getinge la Cahlène, France) in a class D environment. At the end of the daily preparation, the pharmaceutical isolator containing drugs and medical devices was replenished, sterilized, and maintained under positive air pressure until the next day's preparation run.

Gravimetric physical and chemical analyses (i.e. osmolarity, sodium, and potassium dosage) were carried out on each PN before batch release, then discharged to the NICU. The PNs were delivered to the unit by courier every day before 6:00pm.

Nurses performed routine checks for integrity of the PN, compatibility of PN osmolarity with vascular access, and the identity of the patient. In order to avoid sepsis related to catheter use, the change of PN bags follows national guidelines [11, 12].

FMECA is a prospective analysis of the risks associated with a process. The FMECA process involved the following five steps: (i) constituting a multidisciplinary team; (ii) mapping the process; (iii) identifying failure modes that may affect the process and collecting information on this process, (iv) conducting a criticality analysis of the process to rank the significance of potential failure modes, and (v) developing and implementing corrective actions and outcome measures to reduce the risk [13]. The FMECA risk analysis investigation team included physicians, pharmacists, nurses, pharmacy technicians, and quality engineers. As a first step, the entire process was mapped through a brainstorming session using the Ishikawa method. This made it possible to highlight the main phases of the neonatal parenteral nutrition process (Figure 1). For each step, failure modes were identified, as well as their causes, effects, and current detection methods from the literature. Adverse events were reported, then the final brainstorming session took place. All identified failure modes were grouped into a table. For each failure mode, participants were invited to individually complete an online survey to rate severity (S), occurrence (O), and detection (D) according to a criticality-adapted scale (Table 1) from the French public health agency (Haute Autorité de Santé, HAS) [14]. Severity is the impact on the patient (ranging from disturbance to death) or the process; Frequency is the probability of occurrence of a failure mode (from daily to < once per year), and detectability is the probability that the failure mode will be intercepted before it affects the process. S, O, and D were shown on a 5-point scale where 5 is the highest score. Group members were not required to answer all items as some items may be considered too specific to be analyzed by someone without knowledge. Items with rating

Figure 1: Main process of neonatal parenteral nutrition.

Table 1: Severity, occurrence, and detection scales.

Severity (S)	Occurrence (O)	Detection (D)	Score
Disturbance with no effect on the patient	< Once every year	The system will always detect failure	1: Very low
Mild worsening of patient health, delay and disorganization of service	Once every 6 months	Failure will be easily detectable before action	2: Low
Worsening of patient's health, prolongation of hospitalization, service not rendered by medical staff	Monthly	Failure will be difficult to detect before action	3 = Moderate
Permanent effects on body functions	Weekly	Failure will be detectable during action	4: High
Death or permanent loss of major body functions	Daily or 2–6 times per week	Failure will not be detectable before it occurs	5: Very high

variabilities were rediscussed again at a multidisciplinary meeting to ensure that the item was understood in the same way by the entire group.

The numerical value obtained by multiplying these three factors is the RPN (OxSxD) which was used to grade

the relevance of each step using the median of the scores obtained. This index ranges from 1 to 125 and allows for risk prioritization. The larger the index, the higher the risk of potential failure. Failure modes are classified into 3 criticality classes (RPN < 25: acceptable risk, 25 < RPN < 75: risk under surveillance; RPN > 75: unacceptable risk). The failure modes were classified from the highest to the lowest using the RPN. An RPN value of greater than the 3rd quartile was set and prioritized for the identification of areas of potential corrective actions.

Results

FMECA process management

The FMECA was conducted from March 2018 to August 2018. Sixteen multidisciplinary team meetings consisting of two hours of discussion and brainstorming in groups were required. A total of 24 different professionals participated in at least one of the meetings. These meetings were used to validate the PN pathway process, list the failure modes present in the circuit, and implement corrective measures.

Constituting the multidisciplinary team

The multidisciplinary team consisted of 5 physicians, 4 nurses, 2 quality engineers, 5 pharmacy technicians, and 8 pharmacists (Table 2).

Table 2: Composition of FMECA multidisciplinary group.

Title	Specialty	Seniority	Number
Physician	Neonatalogist	1 to 5 years	2
		> 5 years	3
Pharmacist	Resident	1 to 5 years	2
		> 5 years	1
	Pharmacist specializing in PN	1 to 5 years	2
		> 5 years	3
Pharmacy technician	Pharmacy technician	1 to 5 years	2
		> 5 years	3
		> 5 years	3
Nurse	Head nurse	1 to 5 years	1
		> 5 years	3
Quality engineer	Quality specialist	> 5 years	2

Mapping the process

The process was split into three main steps: prescription, preparation, and administration. Each subprocess was described in detail and validated by the multidisciplinary team. The purpose was to describe, in a very precise manner, each step, starting from the prescription of PN to its administration in the care unit. Two hundreds subprocesses were originally recorded and summarized into the main points that were used for the next steps of the FMECA process (Figure 1).

Identifying failure modes

During 3 study sessions, 99 potential problems were identified based on a literature review of our processes, on our non-conformity reports, and on brainstorming sessions [10, 13, 15]. Twenty-eight problems were identified for prescription, 48 for preparation, and 23 for administration. For the prescription step, failure modes were categorized (Table 3).

Critical analysis of the processes

For each identified risk, the FM, causes, and potential effects were specified by the multidisciplinary team. For instance, for the prescription step the risk “inability of the pharmacist to assess the patient’s nutritional needs” was identified. Potential causes identified by the multidisciplinary team were: lack of training, lack of other information on current treatment or nutritional support,

Table 3: Number of identified risks by subprocess.

Subprocess		Risks identified
PRESCRIPTION	I.1 Clinical and biological assessment	2
	I.2 Prescription act	15
	I.3 Medical validation	3
	I.4 Pharmacy transmission	4
	I.5 Supplementation to the PN or PN prepared in the unit	4
PREPARATION	II.1 Hygiene and personnel protection	2
	II.2 Cleanroom condition	15
	II.3 Receipt of the prescription	3
	II.4 Prescription check	4
	II.5 PN preparation	8
	II.6 Physical and chemical checks	3
	II.7 Hospital preparation packaging	6
	II.8 Raw material preparation	2
	II.9 Sterilization of the isolator	5
ADMINISTRATION	III.1 PN reception	4
	III.2 PN connection	6
	III.3 PN surveillance	4
	III.4 PN supplementation	4
	III.5 PN preparation in the pediatric unit	5

and lack of biological laboratory data available to the pharmacist. The result was an inability of the pharmacist to intercept the errors in a physician’s prescription.

Using each FM, the working group performed ratings of severity, frequency, and non-detectability using an online questionnaire. The median RPN was 12, with scores ranging from 3 to 48 and 25 % of the scores had an RPN > 21.75 (Figure 2). No identified risks were classified as unacceptable risks.

Of last quartile RPNs, 12 FMs were associated with prescription subprocesses. For example, preparation of hospital PN in the care unit (RPN = 48); absence of senior staff at the time of prescription (RPN = 36); prescription does not agree with ESPGHAN recommendations (RPN = 36); and masked drug intake not considered at prescription (RPN = 32). Five risks were associated with the preparation step: inability of pharmacist to assess nutritional and electrolyte needs (RPN = 42); pharmacist not trained in PN validation (RPN = 36); absence of pharmaceutical validation before PN preparation (RPN = 36); PN bags prescription outside pharmacy business hours (RPN = 30), and multiple prescriptions for the same patient (RPN = 27). Eight were associated with a failure mode related to administration. For example, risk of septic

Figure 2: Box plot showing the RPN of each identified risk by subprocess (red: prescription, green: preparation, blue: administration).

contamination during preparation in the care unit (RPN = 42), during “Y” supplementation (RPN = 36) or handling (RPN = 31.5), delayed administration due to low flow delivery and dead volume (RPN = 30), and error when supplementing the hospital preparation within the unit (RPN = 28) (Table 4).

Discussion

This study reports on a complete analysis of the failure modes, effects, and criticality analysis (FMECA) of the whole parenteral nutrition process. This process, involving 24 participants and 9 meetings, allowed us to identify 15 risks for 3 major steps of the PN process.

To our knowledge, this study is the first in France to focus on the entire PN process. Previous studies focusing on one step have shown that the preparation step [10] or the administration step [16] are subprocesses with specific risks. Only one study, conducted in Canada by Boulé et al.,

has analyzed the whole process using a multidisciplinary approach and focusing on connections between the subprocesses [13]. Detectability scores may vary among stakeholders, and this is a subjective interpretation. For example, the detectability score for the risk “prescription not faxed to pharmacy” varies depending on the stakeholders. The score was 15 for doctors, whereas it was 27 for pharmacists. These differences were re-discussed in the multi-disciplinary group and led to a deeper understanding of the different subprocesses by the whole working group. Unlike other studies, we preferred to calculate the RPN using the median rather than using the mean [15] or a single consensus score [13] in order to have a better description of the distribution of responses. The median is less influenced by extreme scores than the mean.

FMECA is a tool for structuring the risk mapping of a process. It is easily applicable in hospitals [15, 17] and has already shown its usefulness in risk assessment of PN compounding processes [10], and more generally in pediatrics, in prescribing and administering drugs [18]. Unlike many other risk analysis methods, FMECA focuses on interfaces between different areas of the pathway, such as the transmission stage of PN requirements. It enables us to meet our objective by identifying and prioritizing the risks facing the various participants in the PN pathway. The establishment of a multidisciplinary working group was very much appreciated and enabled all the participants involved in the pathway to gather around a table in order to encourage dialogue and exchange ideas. The presence of a pharmacist, shared by the two areas of activity, made it possible to facilitate these exchanges between the two departments and contributed to the complete analysis of the PN pathway. Pharmacists not only play an important role in the preparation of hospital PN preparations, but also in quality improvement, management, education, and research related to PN therapy, providing clinical management of the patient [19]. The variety of participants provided a large range of experience and insights, important for carrying out a thorough analysis of failure modes and finding solutions. This allowed us to prioritize actions, which is the goal of any quality approach, while maintaining an acceptable workload. FMECA has identified 99 risks in the parenteral nutrition circuit. Commentaries made by the different members of the interdisciplinary group made it possible to isolate the main risks for each subprocess (Table 3). For each step, prioritization using FMECA allowed the working group to rapidly target issues. For example, for prescription, ESPGHAN guidelines are exhaustive and it takes too long to read and retain the information, so they are of little use as a procedural document in routine practice.

Table 4: Main failure modes and comparative risk priority numbers (RPN) for the major risks.

	Failure mode	Severity (S)	Occurrence (O)	Detection (D)	Risk Priority Number (RPN)
PRESCRIPTION	I.5 Preparation of hospital preparation in the pediatric unit	4	3	4	48
	I.2 Prescription does not agree with ESPGHAN recommendations	3	3	4	36
	I.3 Absence of senior staff at the time of prescription	3	3	4	36
	I.2 Masked Intake of drugs not considered at prescription (e. g. Na ⁺)	2	4	4	32
	I.1 Dosage error in relation to weight	3	3	3	27
	I.4 Prescription not sent to pharmacy	3	3	3	27
	I.5 Prescription of a supplement without validation by senior staff	3	3	3	27
	I.2 Prescription error (total intake) as NP prescription separately	2.5	3	3.5	26,25
	I.5 Prescription error during supplementation	3.5	2	3.5	24,5
	I.1 Confusion of patient identity	4	2	3	24
	I.3 Prescription not performed by a physician	4	2	3	24
	I.1 Disagreement with the biological assessment	3	2,5	3	22,5
FABRICATION	II.4 Inability to assess nutritional and electrolyte needs	3	4	4	48
	II.4 Pharmacist not trained in parenteral nutrition validation	3	4	3	36
	II.4 Absence of pharmaceutical validation before hospital preparation production	3	4	3	36
	II.3 Need to outsource nutrition hospital preparation outside of pharmacy business hours	2.5	3	4	30
	II.3 Multiple prescriptions for the same patient	3	3	3	27
ADMINISTRATION	III.4 Septic contamination of preparation when manufacturing in the care unit	3.5	3	4	42
	III.5 Septic contamination of preparation when added to Y	3	3	4	36
	III.2 Septic contamination of preparation during handling	3	3	3,5	31,5
	III.2 Effective administration delayed due to low flow from the prescribed bag on the day of PN	3	4	2.5	30
	III.5 Error when supplementing the bag in the unit (dose, solutions)	3,5	2	4	28
	III.5 Excessive osmolarity for the route of administration	3	3	3	27
	III.1 Lack of delivery tracking	1	5	5	25
	III.4 Supplementation not corresponding to the patient's needs (solute and/or dose error)	4	2	3	24

S, O, D ranged from 1 to 5; RPN ranged from 1 to 125

Furthermore, the data in the literature show that the use of a medical protocol enables the standardization of practices within the same care unit and improves children's growth [20]. This protocol needs to closely follow the recommended contributions and the ways at first [21]. During the FMECA, the failure mode "prescription does not agree with ESPGHAN recommendations" appears among those having one of the highest RPN (RPN = 36). The working group was created to establish a reference table for prescription and was able to meet regularly to standardize practices, simplify the application of the recommendations, and culminate in the creation of a validated institutional procedure. Another example is electronic

prescription: Electronic prescription would reduce the RPN of many failure modes listed during the AMDEC (Table 4). Several studies show better nutritional management of patients in care units in which there is electronic prescription [4, 22]. In addition, the use of pediatric-specific software for prescribing reduces the risk of errors and helps secure the circuit [23]. Electronic prescription will secure several steps, such as taking into account hidden intake of substances during the PN prescription and making an accurate calculation of daily water intake for newborns when prescribing. It will allow pharmacists to have more visibility of the total nutritional intake received by the child, leading to a more comprehensive

pharmaceutical validation. During the FMECA, the failure mode “inability to assess nutritional and electrolyte needs” has the highest RPN of the preparation subprocesses (RPN = 48). In order to promote general knowledge of PN among the various participants, the working group proposed setting up training sessions. The idea was to conduct these sessions in a mixed-professional pair (e. g. physician and pharmacist) or trio (e. g. physician, pharmacist, and nurse) and adapt the content to the audience (residents, physicians, nurses, pharmacists, pharmacy technicians). During these courses, general information about the PN pathway was presented (prematurity, parenteral nutrition, nutritional needs, and routes of administration), then the various stages of the circuit were explained in detail (prescription, pharmaceutical validation, preparation, delivery, administration).

For administration, FMECA identified several risks associated with nurses’ use of PN, such as PN with an osmolarity > 800 mOsm/L administered with a peripheral venous line. The multidisciplinary working groups proposed implementing national recommendations [24]. Good practices recommendations for PN in neonatology have recently reiterated that at least five controls must be performed before administration of a mixture of PN: patient identification, matching content with prescription, date of expiry of hospital preparations, and integrity and appearance of contents [25]. A 2011 Brest Hospital study of infusion management practices also showed heterogeneity in practices among nurses [16].

FMECA is an approach requiring the planning of meetings to carry out the phases of identification and analysis of failure modes followed by proposals for corrective actions. To obtain effective results, the meetings must be well prepared and require the investment of a key participant to oversee the FMECA for every stage of the process. The description of risks is a stage which calls on the experience of every participant and could seem subjective [26].

The number of adverse events in our institution was probably underestimated due to underreporting, as seen in pharmacovigilance [27], especially when they were not serious adverse event. This is due to lack of time for filling in records and avoidance of conflicting situations between the different departments [28]. For instance, we regularly encounter problems of delayed receipt of compounding orders, but this type of problem was often resolved when encountered and not reported. Thus, a quality policy based only on *a posteriori* analysis of adverse events would only focus on a few points, lacking a whole process analysis. The FMECA was a very

complementary approach, as an *a priori* analysis, to obtaining a fast response to an adverse event.

Although the process may be specific to our establishment (e. g. production inside an pharmaceutical isolators with positive air pressure), it can be adapted to each establishment by making some adjustments in prescription and preparation methods. For example, compounding under a microbiological safety cabinets [25] would present other specific hazards. The analysis of the entire PN process conducted as part of this study using FMECA would be of great help in starting a quality plan for the PN process, regardless of the size and specificity of the unit. The development of clinical pharmacies also makes it possible to secure the PN pathway. The presence of a pharmacist in a department can make it possible to detect problems early, at the time of prescription. These professionals can take into account the problems encountered by the various participants to continuously improve the process. The development of clinical pharmacies has enabled the pharmaceutical validation of PN prescriptions before preparation in compliance with national recommendations [6].

Conclusion

This study analyzed the whole parenteral nutrition process using the failure modes, effects, and criticality analysis (FMECA) method. This method allowed us to identify 99 risks and to prioritize 25 of the PN processes. This quality procedure was easy to implement, did not only rely on adverse event analysis, and reinforced multidisciplinary teamwork. The improvement plan focuses on specific tasks as well as connections between subprocesses. The FMECA has made it possible to secure the circuit by reducing the risks thanks to the implementation of continuous training, the drafting of procedures, pharmaceutical validation and the establishment of regular exchanges between the pharmacy and the NICU to discuss the problems of each. The pharmacist, who oversees the entire process, acts as a liaison between the clinical department and the pharmacy.

References

1. Mihatsch WA, Braegger C, Bronsky J, Cai W, Campoy C, Carnielli V, et al. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition. Clin Nutr 2018;37:2303–5.
2. Joosten K, Embleton N, Yan W, Senterre T, Braegger C, Bronsky J, et al. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: energy. Clin Nutr 2018;37:2309–14.

3. Katoue MG. Role of pharmacists in providing parenteral nutrition support: current insights and future directions. *Integr Pharm Res Pract* 2018;7:125–40.
4. Fischer CJ, Maucourt-Boulch D, Essomo Megnier-Mbo CM, Remontet L, Claris O. Early parenteral lipids and growth velocity in extremely-low-birth-weight infants. *Clin Nutr* 2014;33:502–8.
5. Lapillonne A, Carnielli VP, Embleton ND, Mihatsch W. Quality of newborn care: adherence to guidelines for parenteral nutrition in preterm infants in four European countries. *BMJ Open* 2013;3:e003478.
6. Intruction DGOS/PF2/DGS/PP2/2015/85.pdf [Internet]. [cité 14 juin 2018]. Disponible sur: http://solidarites-sante.gouv.fr/fichiers/bo/2015/15-04/ste_20150004_0000_0056.pdf.
7. Evaluation des pratiques en matière de nutrition parentérale pédiatrique [Internet]. [cité 2 mai 2018]. Disponible sur: <http://www.igas.gouv.fr/IMG/pdf/2014-168R.pdf>.
8. MacKay M, Anderson C, Boehme S, Cash J, Zobell J. Frequency and severity of parenteral nutrition medication errors at a large children's hospital after implementation of electronic ordering and compounding. *Nutr Clin Pract* 2016;31:195–206.
9. Sacks GS, Rough S, Kudsk KA. Frequency and severity of harm of medication errors related to the parenteral nutrition process in a large university teaching hospital. *Pharmacotherapy* 2009;29:966–74.
10. Embleton ND, Simmer K. Practice of parenteral nutrition in VLBW and ELBW infants. In: Koletzko B, Poindexter B, Uauy R, editors. *World review of nutrition and dietetics* [Internet]. Basel: S. KARGER AG, 2014 cité 3 mai 2018:177–89. Disponible sur: <https://www.karger.com/Article/FullText/358466>.
11. van der Kooi TII, Wille JC, van Benthem BH. Catheter application, insertion vein and length of ICU stay prior to insertion affect the risk of catheter-related bloodstream infection. *J Hosp Infect* 2012;80:238–44.
12. Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 28 Déc 2006;355:2725–32.
13. Boulé M, Lachapelle S, Collin-Lévesque L, É D, Nguyen C, Fournier-Tondreau M, et al. Failure mode, effect, and criticality analysis of the parenteral nutrition process in a mother-child hospital: the Ameliore study. *Nutr Clin Pract* 2018;33:656–66.
14. Analyse des modes de défaillances et de leurs effets (AMDE) - fiche 26 [Internet]. HAS; [cité 21 févr 2019]. Disponible sur: <https://www.has-sante.fr/portail/upload/docs/application/pdf/2012-04/fiche26.pdf>.
15. Wetterneck TB, Skibinski KA, Roberts TL, Kleppin SM, Schroeder ME, Enloe M, et al. Using failure mode and effects analysis to plan implementation of smart i.v. pump technology. *Am J Health-Syst Pharm AJHP Off J Am Soc Health-Syst Pharm* 15 août 2006;63:1528–38.
16. Le Reste C, Fiedler A, Dubois S, Dewailly A, Le Du I, Cogulet V. Comment promouvoir le respect des bonnes pratiques de perfusion en allant à la rencontre des soignants ? *Ann Pharm Fr* 2016;74:232–43.
17. Burgmeier J. Failure mode and effect analysis: an application in reducing risk in blood transfusion. *Jt Comm J Qual Improv* 2002;28:331–9.
18. Lago P, Bizzarri G, Scalzotto F, Parpaiola A, Amigoni A, Putoto G, et al. Use of FMEA analysis to reduce risk of errors in prescribing and administering drugs in paediatric wards: a quality improvement report. *BMJ Open* 2012;2:e001249.
19. Mirtallo JM. Advancement of nutrition support in clinical pharmacy. *Ann Pharmacother* 2007;41:869–72.
20. Stefanescu BM, Gillam-Krakauer M, Stefanescu AR, Markham M, Kosinski JL. Very low birth weight infant care: adherence to a new nutrition protocol improves growth outcomes and reduces infectious risk. *Early Hum Dev* 1 mars 2016;94:25–30.
21. Ayers P, Adams S, Boullata J, Gervasio J, Holcombe B, Kraft MD, et al., A.S.P.E.N. parenteral nutrition safety consensus recommendations: translation into practice. *Nutr Clin Pract Off Publ Am Soc Parenter Enter Nutr* 2014;29:277–82.
22. Skouroliakou M, Koutri K, Stathopoulou M, Vourvouhaki E, Giannopoulou I, Gounaris A. Comparison of two types of TPN prescription methods in preterm neonates. *Pharm World Sci PWS* 2009;31:202–8.
23. Potts AL, Barr FE, Gregory DF, Wright L, Patel NR. Computerized physician order entry and medication errors in a pediatric critical care unit. *Pediatrics* 2004;113:59–63.
24. Kolaček S, Puntis JW, Hojsak I, Braegger C, Bronsky J, Cai W, et al. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: venous access. *Clin Nutr* 2018;37:2379–91.
25. Sladana P. Nutrition parentérale en néonatalogie Méthode Recommandations pour la pratique clinique. 2018; 74.
26. Shebl NA, Franklin BD, Barber N. Is failure mode and effect analysis reliable? *J Patient Saf* 2009;5:86–94.
27. Vallano A, Cereza G, Pedròs C, Agustí A, Danés I, Aguilera C, et al. Obstacles and solutions for spontaneous reporting of adverse drug reactions in the hospital: obstacles and solutions for reporting adverse drug reactions. *Br J Clin Pharmacol* 27 Sept 2005;60:653–8.
28. Bénét T, Gagnaire J. Les freins à la déclaration des événements indésirables liés aux soins : une étude transversale au groupe hospitalier Édouard Herriot, CHU de Lyon. *BEH* 18 juin 2013;24–5.