UNIL | Université de Lausanne
Faculté de biologie et de médecine

Centre hospitalier universitaire vaudois

Mémoire de Maîtrise en médecine No 3393

Adverse events and associated factors during intra-hospital neonatal transportation: a prospective observational study

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Lausanne, 2017

ABSTRACT

INTRODUCTION

Hospitalized neonates often require internal transportation to perform diagnostic or therapeutic procedures that cannot be done at the bedside. A number of studies attest the risk of intra-hospital transportation of adults and children hospitalized in intensive care, but literature concerning newborns is sparse.

OBJECTIVES

Determine the incidence of complications during intra-hospital transportation of newborns, identify neonatal or transport factors associated with adverse events during transport and assess physiological changes occurring during these transports.

METHODOLOGY

We conducted a prospective observational study from the 1/6/15 to the 1/6/16 in the NICU of the University Hospital of Lausanne, Switzerland. All newborns hospitalized in the NICU undergoing intra-hospital transportation were included.

RESULTS

138 newborns of a median gestational age of 37 weeks (Q1-Q3 30-39 weeks) and of birth weight 2470g (Q1-Q3 1296-3200 g) underwent 429 intra-hospital transports for diagnostic or therapeutic procedures. Reasons for transport included 130 MRIs (30%), 98 surgeries (23%), 65 ultrasounds (15%), 42 endoscopies (10%), 20 CT scans (5%), and 74 other reasons, including TOGDs, enemas and CUMs. 103 adverse events occurred during 79 (18.4%) intra-hospital transports, including 24 (5.6%) desaturations, 22 (5.1 %) agitations, 20 (4.5%) hypothermia events. No adverse event was moderate, severe or led to death of the newborn. Factors associated with complicated transports included low gestational weight and age, underlying

cardiovascular disease or symptoms requiring transport, the use of morphine and of mechanical ventilation, return transports, time out of NICU and transports from surgery and bronchoscopy rooms. There was no significant modification of vital signs during transportation in a selected group of mechanically ventilated newborns.

CONCLUSION

This study confirms that there remains a high number of low-risk events during intra-hospital transportation of newborns. This should raise awareness among staff attending diagnostic and therapeutic procedures outside the NICU, but also among transport staff when confronted to newborns of with transport, material or patient-related characteristics associated with adverse events. Absence of severe complications indicates that newborns can be safely transported within the hospital. Nonetheless, the significant resources required for a safe transport advocates for more procedures to be performed at the bedside.

ABBREVIATIONS

NICU	Neonatal intensive care unit
CT	Computed tomography
MRI	Magnetic resonance imaging
SpO2	Blood oxygen saturation
FiO2	Fraction of inspired oxygen
MAP	Mean arterial blood pressure
WHO	World Health Organization

INTRODUCTION

Hospitalized neonates often require intra-hospital transportation to perform diagnostic or therapeutic procedures that cannot be done at the bedside. Transports represent a potentially unstable environment. The challenge for the healthcare team is to weigh the risks and benefits of the procedures requiring transportation, and to ensure the best possible care during transport.

A number of studies attest that intra-hospital transportations of critically ill adults and children are associated with adverse events, including life-threatening complications[1-7]. Up to 72% of intra-hospital transports are associated with adverse events such as desaturations, agitation, hemodynamic instability, arrhythmia, hypothermia, and equipment-related problems[1-7]. Critically ill patients requiring mechanical ventilation, sedation or hemodynamic support are at the highest risk of developing complications[1,3,5]. Studies performed in the adult and pediatric population have led to the development of standardized procedures and guidelines related to pretransport stabilization, training, organization, and equipment[8-10]. However, due to the specificities of neonatal care and the lack of relevant literature, newborn infants have been excluded from these recommendations.

Inter-hospital transports of newborn infants are relatively common due to the regionalization of neonatal care. Typically, infants born at regional centers can require transportation to tertiary care neonatal intensive care units (NICUs). Emergency transport of critically ill newborn infants to tertiary care NICUs is considered a high risk procedure, with adverse events occurring in up to 36% of transports[11]. Therefore, dedicated neonatal transport teams have been created to ensure quality, safety and efficiency. Specific recommendations exist regarding the organisation, team skills and training, equipment and procedures required for inter-hospital transport of critically ill newborns[12-13].

Newborn infants can require transport within the hospital in order to perform surgery or diagnostic procedures such computed tomography (CT) scan, magnetic resonance imaging (MRI) and gastrointestinal contrast studies. Yet, few studies have

investigated the complications of intra-hospital transports in newborns. A 26% rate of adverse events was observed during intra-hospital transportation of newborn infants in a Brazilian hospital[14]. Prematurity and severity of illness, including the need for supplementary oxygen were identified as risk factors for developing complications during transport[14-15].

Given the gaps in the current state of knowledge concerning intra-hospital transportation of neonates and the potential for improvement of medical care in this field, we performed a prospective observational study. The goals of the study were: i) determine the incidence of adverse events during internal transport of infants hospitalized in the NICU of the University Hospital of Lausanne, ii) to identify potential neonatal or transport related risk factors leading to these complications, and iii) to assess the physiological changes occurring during intra-hospital transports of newborn infants.

METHODS

Study design

We conducted a prospective observational study in the 40 bed tertiary care medical and surgical NICU of the University Hospital of Lausanne, Switzerland. The study was approved by the Cantonal Ethics Committee of Vaud (Lausanne, Switzerland). The need for informed consent was waived due to the observational nature of the study.

Study population

Infants hospitalized in the NICU who underwent intra-hospital transportation between June 1, 2015 and May 31, 2016 were eligible for the study. An intra-hospital transport was defined as transport outside the NICU, but within the hospital for a diagnostic or a therapeutic intervention. For patients that underwent multiple transports, each transport was considered a separate event. Transports from the delivery room to the NICU, as well as ambulance or helicopter transports were excluded from the study.

Transports

All transports were performed by NICU staff. Physicians and nurses working in our NICU receive systematically a specific training regarding transport and equipment used for transport, and are implicated in both intra- and inter-hospital transport. The number and type of professionals and equipment involved in each transport was decided depending on the severity of illness and the needs of the patient. Transports were all conducted inside the hospital, had a length of approximately 200 meters and required between two and three elevator lifts.

Data collection and management

Healthcare professionals present during the transport collected data through a case report form. Information concerning the patient's demographics and clinical characteristics, the transport (indication, date, duration, destination, number and type of staff involved), adverse events and interventions was recorded. Vital signs (temperature, blood pressure, heart rate, respiratory rate, oxygen saturation (SpO2) and fraction of inspired oxygen (FiO2)) were collected within 5 minutes before and after the transport, with an additional measure during transportation for patients that had continuous monitoring of vital signs. Respiratory rate was only measured before and after transportation for practical reasons. Additional data was obtained from medical charts and through the clinical electronic information system Metavision®.

Adverse events were defined as any event considered by healthcare givers as a danger for the health of the newborn, or vital signs displaying values outside reference ranges. The following reference ranges were used: oxygen saturation 85-95% for preterm infants (< 37 weeks of gestation), 92-97% for term infants (≥ 37 weeks of gestation); hypothermia was defined as a temperature < 36°C, hyperthermia was defined as a temperature > 38°C; bradycardia was defined as a heart rate < 90/min for preterm infants, and < 80/min for term infants; hypotension was defined as mean arterial blood pressure (MAP) < corrected or postmenstrual age. Due to the lack of upper reference ranges for heart rate and blood pressure in newborns, evaluation of tachycardia and hypertension were made by the transport team.

The severity of every adverse event was defined according to the World Health Organization (WHO), depending on the level of harm[24]:

• None (no harm) – patient outcome is not symptomatic or no symptoms detected and no treatment is required.
• Mild (low harm) – patient outcome is symptomatic, symptoms are mild, loss of function or harm is minimal or intermediate but short term, and no or minimal intervention (e.g., extra observation, investigation, review or minor treatment) is required.
• Moderate – patient outcome is symptomatic, requiring intervention (e.g., additional operative procedure; additional treatment), an increased length of stay, or causing permanent or long term harm or loss of function.
• Severe – patient outcome is symptomatic, requiring life-saving intervention or major surgical/medical intervention, shortening life expectancy or causing major permanent or long-term harm or loss of function.
• Death – on balance of probabilities, death was caused or brought forward in the short term by the incident.

Severity of adverse events was established by the four investigators (RD, CS, CF, EG) leading the study. Each investigator independently reviewed every adverse event and rated its severity according to the WHO[24]. Events for which investigators gave a different grade of severity were discussed in a focus group to reach a consensus.

Data analysis

Baseline clinical characteristics were described by showing the median and the first and third quartiles (Q1–Q3) for continuous variables, and numbers and percentages for categorical variables. Group comparisons were performed using Student t tests and Chi Squared tests, respectively. Findings were considered statistically significant when $P < 0.05$.

RESULTS

In all, 582 intra-hospital transports of newborn infants were performed between June 1, 2015 and May 31, 2016. 429 (429/582, 74%) transports performed in 138 infants had adequate documentation and could be included in the study.

Population characteristics

Median gestational age of the patients was 37 weeks (Q1-Q3 30-39 weeks), and median birth weight was 2470g (Q1-Q3 1296-3200 g) (**Table 1**). Fifty-two (52/138, 38%) of the transported newborns were female, and the median number of transports per patient was 2 (Q1-Q3 2-4). Median Apgar scores at 1 minute, 5 minutes and 10 minutes were 6 (Q1-Q3 2-8), 8 (Q1-Q3 6-9) and 9 (Q1-Q3 8-10), respectively. Among the transported newborns, the most common reasons for hospital admission were prematurity (54/138, 40%), congenital malformations (33/138, 24%) and asphyxia or seizures (20/138, 15%).

Among the 138 transported infants, 53 (53/138, 38%) presented at least one adverse event during transportation. Population characteristics and comparison between patients with adverse events and those without adverse events are presented in Table 1.

Table 1: Population characteristics

	All patients (n=138)	Patients with adverse event(s) (n=53)	Patients without adverse event (n=85)	p-value
Gender, female, n (%)	52 (38)	20 (38)	32 (38)	p = 0.992[#]
Gestational age, weeks [median (Q1-Q3)]	37 (30-39)	34 (28-38)	38 (34-39)	p < 0.001[*]
Birth weight, g [median (Q1-Q3)]	2470 (1269-3205)	1730 (934-2898)	2780 (1793-3363)	p < 0.001[*]
Birth weight percentile, [median (Q1-Q3)]	30 (9-50)	30 (9-50)	30 (9-51)	p = 0.801[*]
1 minute Apgar score, [median (Q1-Q3)]	6 (2-8)	6 (3-8)	6 (2-9)	p = 0.611[*]
5 minutes Apgar score, [median (Q1-Q3)]	8 (6-9)	8 (6-9)	9 (6.25-9)	p = 0.935[*]
10 minutes Apgar score, [median (Q1-Q3)]	9 (8-10)	9 (8-10)	9 (8-10)	p = 0.999[*]
Reason for hospital admission:				
Prematurity, n (%)	54 (39)	28 (52)	26 (31)	p = 0.009[#]
Congenital malformation, n (%)	33 (24)	12 (23)	21 (25)	p = 0.782[#]
Asphyxia/seizures, n (%)	20 (14)	4 (8)	16 (19)	p = 0.067[#]
Respiratory distress, n (%)	7 (5)	3 (6)	4 (5)	p = 0.804[#]

Infection, n (%)	5 (4)	1 (2)	4 (5)	p = 0.389[#]
Other, n (%)	17 (12)	6 (11)	13 (15)	p = 0.510[#]
Number of transports per patient, [median (Q1-Q3)]	2 (2-4)	3 (2-5.5)	2 (2-2.5)	p < 0.001[*]

Transport characteristics

Median postnatal age at the time of transport was 12 days (Q1-Q3 5-45), median corrected age was 39 weeks (Q1-Q3 37-42), and median weight at time of transport was 2880g (Q1-Q3 2310-3460) (**Table 2**). Underlying conditions or symptoms requiring transport were digestive (119/429, 28%), neurological (89/429, 21%), cardiovascular (44/429, 10%), urologic (31/429, 7%), polymalformative syndromes (30/429, 7%) and respiratory (25/429, 6%). Indications for transport included MRI (130/429, 30%), surgery (98/429, 23%), ultrasound (65/429, 15%), bronchoscopy (42/429, 10%), CT scan (20/429, 5%), and other indications (74/429, 17%) including gastro-intestinal contrast studies and voiding cystourethrograms.

Departure locations were mostly radiology units (127/429, 30%), the NICU intensive care unit (115/429, 27%), intermediate care (56/429, 13%) and specialized care (59/429, 14%), operating rooms (35/429, 8%) and bronchoscopy rooms (26/429, 6%). Arrival locations were radiology units (134/429, 31%), the NICU intensive care unit (96/429, 22%), intermediate care (50/429, 12%) and specialized care (56/429, 13%), operating rooms (48/429, 11%) and bronchoscopy rooms (29/429, 7%). The median number of caregivers during transport was 2 (Q1-Q3 1-2). A nurse was present during most transports (415/429, 97%). Median duration of transport was 10 minutes (Q1-Q3 8-14 min). For return transports, i.e. transports to the NICU, median time out of the NICU was 97 minutes (Q1-Q3 70-138 minutes).

Newborns were transported in incubators (138/429, 32%), strollers (68/429, 16%), Nomag© incubator systems (68/429, 16%), radiant warmers (67/429, 16%) and beds (45/429, 10%). Forty percent of the transports (170/429) were performed under respiratory support including invasive ventilation (85/429, 20%), non-invasive ventilation (43/429, 10%), and nasal canulae (42/429, 10%). Patients had vascular access in sixty eight percent of transports, including peripheral venous catheters

(210/429, 49%), peripherally inserted central venous catheters (PICC) (118/429, 27%), umbilical artery catheters (63/429, 15%), umbilical venous catheters (43/429, 10%) and peripheral arterial catheters (14/429, 3%). Gastric tubes were present in 289/429 (67%) of transports, and bladder catheters in 27/429 (6%). Vasoactive drugs were administered in 26/429 (6.5%) of transports, and continuous infusions of morphine in 87/429 (20%) of transports.

Table 2. Transport characteristics

	All transports (n=429)	Transports with adverse event(s) (n=79)	Transports without adverse event (n=350)	p-value
Female gender, n (%)	143 (33)	26 (33)	117 (33)	p = 1
Gestational age, weeks [median (Q1-Q3)]	37 (30-39)	34 (27-38)	37 (31-39)	p < 0.001
Birth weight, g [median (Q1-Q3)]	2260 (1128-3100)	1690 (867-2610)	2400 (1394-3200)	p < 0.001
Birth weight percentile, [median (Q1-Q3)]	25 (7-50)	25 (7-40)	25 (7-50)	p = 0.639
1 minute Apgar score, [median (Q1-Q3)]	6 (3-8)	6 (3-8)	6 (3-8)	p = 0.910
5 minutes Apgar score, [median (Q1-Q3)]	9 (6-9)	8 (6-9)	9 (6-9)	p = 0.464
10 minutes Apgar score, [median (Q1-Q3)]	9 (8-10)	9 (8-10)	9 (8-10)	p = 0.964
Reason for hospital admission:				
Prematurity, n (%)	173 (40)	44 (56)	129 (37)	p = 0.002
Congenital malformation, n (%)	124 (29)	17 (22)	107 (31)	p = 0.109
Respiratory distress, n (%)	20 (5)	3 (4)	17 (5)	p = 0.686
Asphyxia/Convulsions, n (%)	49 (11)	5 (6)	44 (13)	p = 0.115
Infection, n (%)	12 (3)	1 (1)	11 (3)	p = 0.361
Other, n (%)	51 (12)	8 (10)	43 (12)	p = 0.592
Postnatal age at the time of transport, days [median (Q1-Q3)]	12 (5-45)	16 (7-56)	12 (5-42)	p = 0.461
Corrected age at the time of transport, weeks [median (Q1-Q3)]	39 (37-42)	38 (33-41)	39 (37-42)	p = 0.017
Corrected age < 37 weeks at the time of transport, n (%)	115 (27)	29 (38)	86 (25)	p = 0.022
Weight at the time of transport, g [median (Q1-Q3)]	2880 (2310-3460)	2660 (1905-3300)	2995 (2348-3503)	p = 0.008
Underlying conditions or symptoms requiring transport				
Digestive, n (%)	119 (28)	23 (29)	96 (27)	p = 0.700
Neurological, n (%)	89 (21)	13 (16)	76 (22)	p = 0.322
Cardiovascular, n (%)	44 (10)	13 (16)	31 (9)	p = 0.038
Urologic, n (%)	31 (7)	4 (5)	27 (8)	p = 0.428
Polymalformative syndrome, n (%)	30 (7)	5 (6)	25 (8)	p = 0.823
Respiratory, n (%)	25 (6)	8 (10)	17 (5)	p = 0.064
Infectious, n (%)	5 (1)	0 (0)	5 (1)	P = 0.289
Other, n (%)	64 (15)	8 (10)	56 (16)	p = 0.199

Reason for transport:				
MRI, n (%)	130 (30)	22 (28)	108 (31)	p = 0.599
Ultrasound, n (%)	65 (15)	7 (9)	58 (17)	p = 0.084
Surgery, n (%)	98 (23)	26 (33)	72 (21)	p = 0.019
Bronchoscopy, n (%)	42 (10)	14 (18)	28 (8)	p = 0.008
CT scan, n (%)	20 (5)	1 (1)	19 (5)	p = 0.113
Other, n (%)	74 (17)	9 (11)	65 (19)	p = 0.127
Return transport, n (%)	201 (47)	47 (59)	154 (44)	p = 0.013
Departure location:				
NICU, intensive care, n (%)	115 (27)	19 (24)	96 (27)	p = 0.540
NICU, intermediate care, n (%)	56 (13)	6 (8)	50 (14)	p = 0.111
NICU, specialized care, n (%)	59 (14)	7 (9)	52 (15)	p = 0.162
Operating room, n (%)	35 (8)	15 (18)	20 (6)	p < 0.001
Pediatric intensive care unit, n (%)	0 (0)	0 (0)	0 (0)	
Radiology level 5 and 7, n (%)	127 (30)	18 (23)	109 (31)	p = 0.141
Bronchoscopy, n (%)	26 (6)	14 (18)	12 (3)	p < 0.001
Pediatric ward, n (%)	4 (1)	0 (0)	4 (1)	p = 0.340
Other, n (%)	7 (1)	0 (0)	7 (2)	p = 0.205
Arrival location:				
NICU, intensive care, n (%)	96 (22)	34 (43)	62 (18)	p < 0.001
NICU, intermediate care, n (%)	50 (12)	10 (13)	40 (11)	p = 0.760
NICU, specialized care, n (%)	56 (13)	3 (4)	53 (15)	p = 0.007
Operating room, n (%)	48 (11)	6 (8)	42 (12)	p = 0.261
Pediatric intensive care unit, n (%)	3 (1)	2 (3)	1 (1)	p = 0.030
Radiology level 5 and 7, n (%)	134 (31)	19 (24)	115 (33)	p = 0.127
Bronchoscopy, n (%)	29 (7)	5 (6)	24 (7)	p = 0.866
Pediatric ward, n (%)	6 (1)	0 (0)	6 (2)	p = 0.241
Other, n (%)	7 (2)	0 (0)	7 (2)	p = 0.205
Duration of transport, min [median (Q1-Q3)]	10 (8-14)	10 (9.25-13)	10 (8-13)	p = 0.002
Time out of NICU for return transports, min [median (Q1-Q3)]	97 (70-138)	129.5 (94-175)	90 (60-127)	p = 0.002
Number of caregivers present during transport:	2 (1-2)	2 (2-3)	2 (1-2)	p < 0.001
Nurse, n (%)	415 (97)	78 (99)	337 (96)	p = 0.630
Assistant nurse, n (%)	74 (17)	20 (25)	54 (15)	p = 0.044
Resident, n (%)	92 (21)	19 (24)	73 (21)	p = 0.596
Registrar, n (%)	126 (29)	41 (52)	85 (24)	p < 0.001
Other, n (%)	99 (23)	20 (25)	79 (23)	p = 0.671
Transport equipment:				
Incubator, n (%)	138 (32)	35 (44)	103 (29)	p = 0.014
Radiant warmer, n (%)	67 (16)	17 (22)	50 (14)	p = 0.126
Bed, n (%)	45 (10)	4 (5)	41 (12)	p = 0.074
Stroller, n (%)	92 (21)	7 (9)	85 (24)	p = 0.002
MR Diagnostics Incubator System Nomag®, n (%)	68 (16)	14 (18)	54 (15)	p = 0.663
Other, n (%)	7 (2)	1 (1)	6 (2)	p = 0.762
Unknown, n (%)	12 (3)	1 (1)	11 (3)	p = 0.350
Respiratory support:				

Invasive ventilation, n (%)	85 (20)	30 (38)	55 (16)	p < 0.001
Non invasive ventilation, n (%)	43 (10)	15 (19)	28 (8)	p = 0.004
Nasal canulae, n (%)	42 (10)	11 (14)	31 (9)	p = 0.184
Unknown, n (%)	10 (2)	1 (1)	9 (3)	p = 0.479
Vascular access				
1 peripheral venous catheter, n (%)	190 (44)	41 (52)	149 (42)	p = 0.168
> 1 peripheral venous catheter, n (%)	20 (5)	6 (8)	14 (4)	p = 0.184
Peripherally inserted central venous catheter, n (%)	118 (27)	38 (48)	80 (23)	p < 0.001
Other central venous catheter, n (%)	27 (6)	6 (8)	21 (6)	p = 0.619
Umbilical artery catheter, n (%)	43 (10)	11 (14)	32 (9)	p = 0.215
Umbilical venous catheter, n (%)	63 (15)	14 (18)	49 (14)	p = 0.425
Peripheral arterial catheter, n (%)	14 (3)	2 (3)	12 (3)	p = 0.672
Vasoactive drugs, n (%)	28 (7)	9 (11)	19 (5)	p = 0.057
Dopamine, n (%)	9 (2)	4 (5)	5 (1)	p = 0.044
Norepinephrine, n (%)	8 (2)	5 (6)	3 (1)	p = 0.001
Prostaglandin E2, n (%)	17 (4)	4 (5)	13 (4)	p = 0.595
Sedation and analgesia				
Morphine, n (%)	87 (20)	29 (37)	58 (17)	p < 0.001
Midazolam, n (%)	3 (1)	1 (1)	2 (1)	p = 0.503
Gastric tube, n (%)	289 (67)	59 (75)	230 (66)	p = 0.132
Duodenal tube, n (%)	2 (0.5)	1 (1)	1 (0.5)	p = 0.251
Bladder catheter, n (%)	27 (6)	7 (9)	20 (6)	p = 0.303
Other equipment, n (%)	8 (2)	4 (5)	4 (1)	p = 0.020

Adverse events

103 adverse events **(Table 3)** occurred during 79/429 (18%) intra-hospital transports. Clinical complications were the most frequently described, including desaturations (24/429, 6%), agitation (22/429, 5 %), hypothermia (20/429, 5%), hyperthermia (11/429, 3%) and hypotension (9/429, 2%).

Thirty one adverse events (31/103, 30%) appeared before transportation, twenty nine of which (97%) during return transports. Nineteen hypothermia events (19/20, 95%) occurred during return transports, mostly from surgery (7) and endoscopy (7). Sixteen hypothermia events were present before transport (15/20, 75%). Five hypotensions (5/9, 56%), five desaturations (5/29, 17%) and five hyperthermia cases (5/11, 45%) were present before transport from various locations.

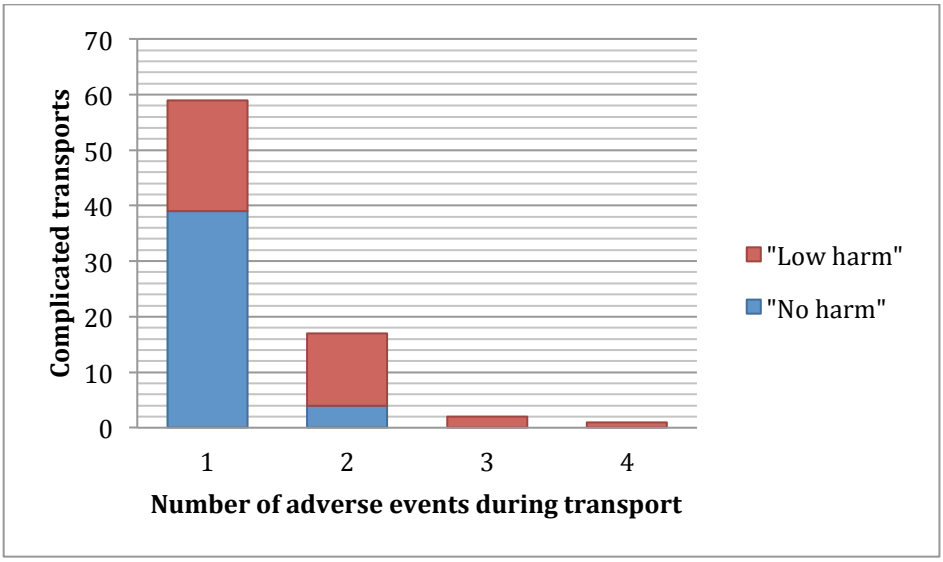
Equipment problems occurred during 8/429 (2%) transports. Among them, two were ventilation defects leading to desaturations, two were monitoring defects, two were blood pressure meter defects and two were transport incubator defects. Five of them were caused by equipment battery problems. There were no reports of medication errors.

Table 3. Adverse events identified during 429 transports

Adverse events during transports	
Desaturation, n (%)	24 (5.6)
Agitation, n (%)	22 (5.1)
Hypothermia, n (%)	20 (4.7)
Hyperthermia, n (%)	11 (2.6)
Hypotension, n (%)	9 (2.1)
Equipment problem, n (%)	8 (1.9)
Bradycardia, n (%)	4 (0.9)
Tachycardia, n (%)	2 (0.5)
Hypertension, n (%)	1 (0.2)
Other, n (%)	2 (0.5)
Total, n (%)	103

Among the complicated transports, 59/79 (75%) presented 1 adverse event, 17/79 (22%) presented 2 adverse events, two of them (2/79, 3%) 3 adverse events and one of them 4 adverse events. Forty three complicated transports (43/79, 54%) were classified as "no harm" and 36/79 (46%) as "low harm" (**Figure 1).** No adverse events were considered as "moderate" or "severe", and no death occurred as a consequence of transportation.

Figure 1. Number of adverse events and classification of complicated transports



Therapeutic interventions were made in 99/429 (23%) transports, most of them being adaptation of the FiO2, occurring in 85/429 transports (20%). Interventions were made in 43/79 (55%) complicated transports.

Comparison of data

Population

Data concerning the studied population was compared between newborns with ≥ 1 complicated transport and newborns with no complicated transport. (See Table 1) Factors significantly associated with the occurrence of at least one adverse event were low gestational age and birth weight, admission for prematurity and a high number of transports.

Transports

We compared complicated transports (with at least one adverse event) and uncomplicated transports. Several patient-related, transport-related and equipment-related factors were significantly associated with adverse events.

Patient-wise, low gestational and corrected age, low birth and actual weight and cardiovascular diseases or symptoms requiring transport were associated with complicated transports. Among the 13 patients requiring transport for a cardiovascular disease or symptom who presented adverse events, nine (9/13, 69%) had patent ductus arteriosus, two (2/13, 15%) had a coarctation of the aorta, one had a transposition of the great arteries and one had a systolic murmur. Reason for transport was mostly surgery (11/13, 85%).

Transports from bronchoscopy and operating rooms and transports heading to the NICU intensive care unit were associated with adverse events. On the other hand, transports headed to the NICU specialized care unit were associated with uncomplicated transports. A longer duration of transport and a longer time out of the NICU were associated with the occurrence of adverse events. A high number of caregivers during transport, as well as the presence of a registrar and of an assistant nurse, were associated with complicated transports.

Equipment-wise, the use of an incubator was associated with adverse events, while the use of a stroller is negatively associated with adverse events. Transport of patients requiring respiratory support including invasive and non-invasion ventilation were associated with adverse events. The presence of a peripherally inserted central venous catheter and of continuous infusion of morphine was associated with a higher occurrence of adverse events.

Vital signs during transport of mechanically ventilated newborns

Vital signs and FiO2 were measured before, during and after 85 transports of mechanically ventilated newborn infants **(Table 4, Figure 2)**. Mean blood pressure was lower before transports with adverse events than before transports without adverse events. FiO2 was higher during transports with adverse events than during transports without adverse events. Body temperature was lower after transports with adverse events than after those without adverse events. Changes in vital signs and FiO2 during and after transports were no statistically significant **(Table 5)**.

Table 4. Vital signs and FiO2 during transport of mechanically ventilated newborns

	Missing values (when > 10%)	All transports (n=85)	Transports with adverse event(s) (n=30)	Transports without adverse event (n=55)	p-value
Heart rate, beats/min, [median (Q1-Q3)]					
Before transport		145.5 (130-163)	145.5 (127-160.5)	146 (130-166.5)	p = 0.561
During transport	10.5%	149 (130-163)	148 (123-164.5)	149 (130-161)	p = 0.693
After transport		145.5 (131.5-159)	145 (116.5-161.5)	146 (135-160)	p = 0.556
Mean blood pressure, mmHg [median (Q1-Q3)]					
Before transport		43 (36-50)	40 (32.5-46)	45.5 (40-50)	p = 0.011
During transport	31.8%	44 (36.5-49)	38 (31-47.5)	45 (40-51)	p = 0.017
After transport	11.8%	42 (36-54)	39 (34-56)	43.5 (39-51)	p = 0.542
Peripheral oxygen saturation, % [median (Q1-Q3)]					
Before transport		96 (94-98)	95 (94-98)	97 (95-98)	p = 0.225
During transport		96 (94-98)	95 (92.5-98.5)	96 (94-98)	p = 0.061
After transport		96 (94-98)	95 (93.98)	96 (95-98)	p = 0.492
Fraction of inspired oxygen, % [median (Q1-Q3)]					
Before transport		30 (25-44)	35 (25-50)	28 (24-40)	p = 0.058
During transport		30 (23-40)	35 (25-40)	26 (22.5-36)	p = 0.049
After transport		28 (23-40)	35 (25-40)	25 (21.5-36)	p = 0.099
Temperature, °C [median (Q1-Q3)]					
Before transport		36.9 (36.5-37.3)	36.8 (35.3-37.4)	36.9 (36.6-37.2)	p = 0.175
During transport	38.8%	36.9 (36.5-37.2)	36.7 (35.6-37.5)	37 (36.7-37.2)	p = 0.417
After transport	14.1%	36.8 (36.4-37.1)	36.3 (36.6-37.2)	36.9 (36.6-37.2)	p = 0.019

Figure 2 A. Median heart rate

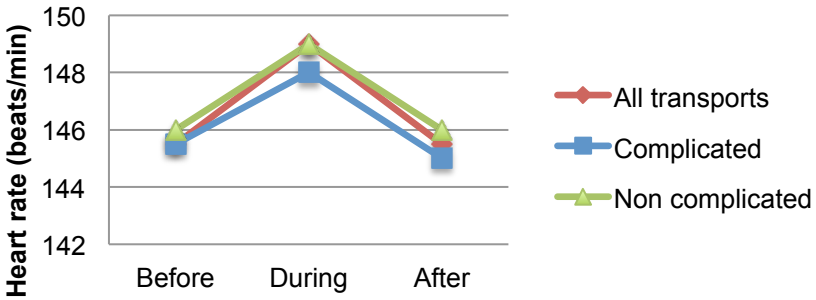


Figure 2B. Median oxygen saturation (SpO2)

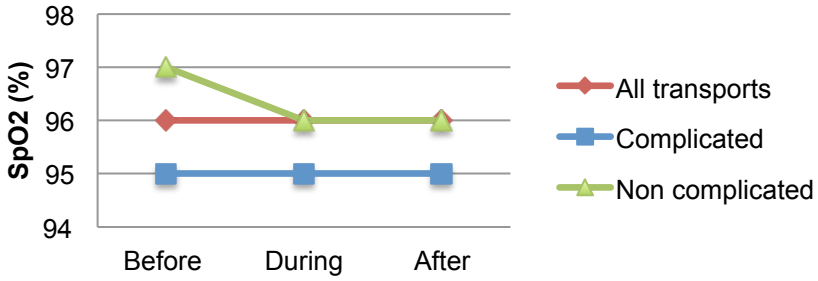


Figure 2C. Median fraction of inspired oxygen (FiO2)

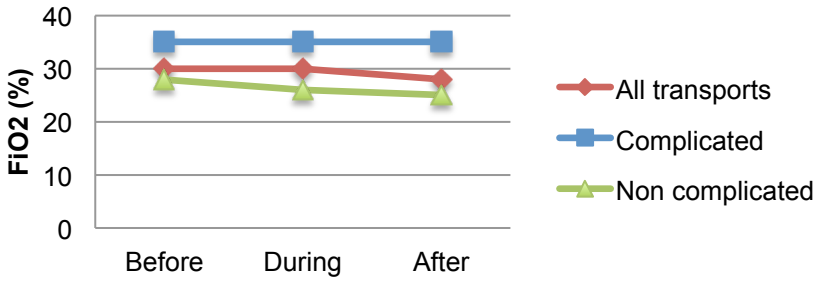


Table 5. Analysis of vital signs

			p
hr_pre	-	hr_dur	0.952
hr_pre	-	hr_post	0.394
hr_dur	-	hr_post	0.847
map_pre	-	map_dur	0.706
map_pre	-	map_post	0.446
map_dur	-	map_post	0.171
sat_pre	-	sat_dur	0.320
sat_pre	-	sat_post	0.702
sat_dur	-	sat_post	0.419
fi_pre	-	fi_dur	0.160
fi_pre	-	fi_post	0.229
fi_dur	-	fi_post	0.724
temp_pre	-	temp_dur	0.188
temp_pre	-	temp_post	0.185
temp_dur	-	temp_post	0.816

DISCUSSION

Intra-hospital transports of newborns are shorter and considered safer than inter-facility transports. Yet, they remain frequent, and have been the subject of very few studies[14-16]. We evaluated the incidence of adverse events during intra-hospital transportation of newborns, and identified underlying characteristics, both of the patient and the transport, that increase the risk of adverse events.

The rate of complicated transports (18%) during our study was lower than the 26-72% range described in newborns, children and adults[1-7, 11, 14]. Several factors might contribute to the relatively low incidence of adverse events observed in our cohort, including the inclusion of all neonates that underwent intra-hospital transport, relatively short distances between the NICU and other intra-hospital facilities at our institution, possible differences in pre-transport stabilization, equipment, training and expertise acquired during both intra- and inter-hospital transportation of newborn infants. The incidence of adverse events is also influenced by definitions. Tachycardia and hypertension were determined by the transport teams in our study. The use of specific definitions for tachycardia and hypertension would have resulted in an increase in the rate of adverse events up to 26% (111/429) in our study. All adverse events observed in our study fell into the low harm and no harm category, and none were considered as moderate, severe or fatal.

Furthermore, we did not find any clinically significant change in vital signs during and after transport, indicating that intra-hospital transport of neonates can be performed with minimal physiological changes. Therefore, although adverse events remain rather frequent, both adequate pre-transport stabilization and quick response to events occurring during transports might prevent the occurrence of severe complications.

Prematurity and associated factors such as low birthweight, low corrected age and low actual weight at the time of transport were associated with a higher incidence of adverse events during transportation. This matches previous studies showing that extreme prematurity (< 28 weeks) and low current weight are the main factors

associated with the occurrence of adverse events during transportation[14-16]. Patients with an underlying cardiovascular condition or symptom had a higher occurrence of adverse events. Unlike the study leaded by Vieira et al.[14-15], we did not find that an underlying CNS condition was associated with higher frequency of adverse events during transportation.

Patients transported to intensive care unit, in other words patients with severe conditions, were more at risk of developing complications. This is consistent with equipment-related elements such as the presence of a PICC line. In contrast, transports to NICU specialized care were associated with fewer adverse events. These elements align with studies showing that severity of illness is a risk factor for adverse events during transport[1,7]. As in studies on adult and pediatric transportation[1,3,5], non-invasive and invasive ventilation, and sedation with morphine were associated with the occurrence of adverse events during transport. Patients undergoing more transports were more at risk of developing at least one adverse event during transport. This can be explained by the fact that patients with severe conditions have longer hospitalizations, undergo several diagnostic or therapeutic procedures, and by the fact that these patients are more frequently exposed to the inherent risk of the transport.

Return transports (i.e. transports from an extra-NICU location to the NICU) were at risk for adverse events. Of note, over 60% adverse events observed during return transport had an onset before transport, and over half of these events were related to hypothermia. Efforts should be made by teams working at each location, in particular during surgery and endoscopy, to maintain a normal body temperature, and by transport team to ensure sufficient pre-transport stabilization.

Duration of transport was higher in complicated transports. Yet, this difference was small and unlikely to be clinically significant. Aside from duration of transport, Bastung et al. found that hyperglycaemia and hypothermia were significantly associated with time spent out of the NICU[16]. Long procedures in critically ill newborns with insufficient pre-transport stabilization could be involved. In our study, a longer time out of the NICU was associated with adverse events.

Several recommendations point out the necessity of having a specialized transport team to guarantee a safer transport[9-11]. In this study, a large number of transport staff as well as the presence of a registrar were associated with a higher rate of complications. This shows that staff was mobilized in response to newborns at risk of developing complications during intra-hospital transportation.

Equipment-related problems occurred during 2% of transports. Such events were less frequent than 9-45% rate described in neonatal, pediatric and adult transportation[2,3,4,5,11,14]. Wallen et al. found that duration of transport was associated with equipment-related events[7]. The difference in occurrence of such events can be explained by the fact that some studies only included mechanically ventilated patients, which require more equipment, and that our transports were relatively short. Nonetheless, there is reason to believe these events are preventable with adequate equipment and preparation.

Non transport related iatrogenic events are frequent in hospitalized newborns, with risk factors similar to those found in neonatal transportation, such as low gestational age, low birth weight, mechanical ventilation and the presence of a central venous line[22]. Over a third of iatrogenic events reported in neonates are preventable[21], which is higher than the rates observed in older children[22-23]. In a prospective study on inter-facility transportation[11], two thirds of adverse events occurring during transportation were perceived as being due to avoidable human errors[11]. Although we did not measure the preventability of adverse events in our study, it is very likely that some events could have been prevented, especially those related to temperature control.

Several limitations to this study should be highlighted. Information on 26% of transports could not be collected due to inadequate documentation. We could not weigh the consequences of adverse events occurring during transportation throughout the patient's individual clinical outcome. Moreover, results may not be entirely transposable to other NICUs due to differences in local organization, staffing, and distance to extra-NICU locations. Multivariate analysis for potential risk factors for adverse events occurring during transport still needs to be performed.

CONCLUSION

This study shows that low-risk adverse events occur during intra-hospital transportation of newborns. Our results should raise awareness among staff attending diagnostic and therapeutic procedures outside the NICU, but also among transport staff when confronted to newborns of low gestational age, or with cardiovascular diseases, or other severe conditions including requirement for respiratory support, and for infants spending prolonged periods out of the NICU for diagnostic and therapeutic procedures. The absence of severe complications and the relatively low incidence of mild adverse events indicate that newborns can be safely transported within the hospital. Yet, this requires specific equipment and training, manpower, and time for preparation of the patient before transport. This advocates for more procedures to be performed at the bedside.

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