How Organizational and Technological Innovations Influence Neonatal Intensive Care Units: A Multiple Case Study on Clinicians' Perceptions

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Abstract. This paper reports an exploratory study of the impact of organizational and technological innovations on health care workers and patient's family within the NICU. Based on the multiple case study method, we conducted a qualitative analysis using both ethnographic interviews and document analysis techniques in order to collect data on the NICU of two largest hospitals. Results have shown that health care workers and patients' families positively perceive the changes in terms of satisfaction and climate when both organizational and technological innovations occur.

Keywords: health care; innovation; NICU.

Introduction

This paper was aimed to investigate the organizational change arising from the innovation adoption within health care industry, and in particular within hospital sector. Innovation is any idea, practice, or material artifact perceived as new by the relevant unit of adoption. The literature has always paid attention to innovation identifying various types such as product innovation, process innovation, marketing innovation, organizational innovation, technological innovation, etc. Innovation is viewed as fundamentally important to organizational competitiveness and effectiveness within for profit sector, yet it has been understudied within the nonprofit sector [1]. Among various types of innovation, we focused on two peculiar types, such as organizational and technological, aimed to investigate their impacts on clinicians, nurses and patients' families.

During last decades many conditions have contributed to make changes in health care sector and to let grow academic attention on the system: managerial process introduced by new laws in health care sector, growing aging of population, new epidemiology conditions induced by health dysfunctional life styles and poverty, and rapid technological revolutionary innovations. With refer to the last topic, it would be very interesting to analyze changes emerging in health sector and, in Neonatal Intensive Care Units (NICU) in particular, which have been interested by radical technological and organizational innovations.

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Many NICU have showed high level of efficacy and efficient learning process in new technological and organizational procedure adoption becoming health care best practices for other ones. In particular, best practices are "a set of interrelated work activities repeatedly utilized by individuals or groups that a body of knowledge demonstrates will yield an optimal result-good patient outcomes" [2, p. 894]. Within NICU, best practices provide better technological and organizational evidences for monitoring and caring pre-term newborns and critically ill infants, which need often immediate and accurate checks and interventions to prevent premature mortality and serious physiological long-term damages [2, 3].

This paper reports an exploratory study within the NICU on health care directors' perceptions of the effects of technological innovations on organization, workers and patient's family. Based on the case study method, we conducted a qualitative analysis using interviews and document analysis, in order to collect data on the NICU of two largest hospitals located in the Southern of Italy: NICU clinician and manager of *AORN Santobono Pausilipon* and NICU clinician and manager of *AORN Azienda Ospedaliera Specialistica dei Colli*. Results from directors' perspective have shown that health care workers and patients' families positively perceive the changes when both organizational and technological innovations occur. On the contrary, when organizational changes do not follow the technological ones, health care workers and patients' families may appear more stressed. To align organizational and technological processes of innovation, health care directors could try to develop organizational capabilities (agility, digital options, and entrepreneurial alertness) and strategic processes (capability-building, entrepreneurial action, and coevolutionary adaptation) suggested by Sambamurthy and colleagues [4], and to join theoretical perspective of Rogers' innovation-diffusion model [5], based on the significant role of perceived attributes of innovations, as determinant of their successful organizational adoption.

Organizational and technological changes in Hospital Neonatal Intensive Care Units

Neonatal Intensive Care Units provide care for premature and very low weight neonates, and critically ill babies born with congenital anomalies. These fragile infants need very high levels of observation and care [6], and a complex organizational structure of support, characterized by interdependent activities, high level of coordination between internal workers and internal and external units and good reliable standardized best practices for optimal patient outcomes [2].

Recent innovations in NICU, in terms of information technology system of monitoring and care of delicate newborns, have significantly influenced perception and performance of care staff, and the quality perception, satisfaction[1] and benefits for

[1] Some Authors [6] individuated seven main dimensions of patient and family satisfaction, such as: admission, nursing and daily care, medical care, information, hospital environment and ancillary staff, overall quality of care and services, recommendations/intentions. They considered patient satisfaction as a dependent variable respect to independent variables such as patient socio-demographic, health and stay characteristics, and organization and activity of

families and neonates patients [6, 7], making the area even more attractive as subject of clinical and organizational analyses.

From an organizational perspective, innovation represents an idea or a practice perceived as new by individuals, groups, or organizations: according to innovation-diffusion model, perceived attributes of innovations significantly affect awareness of an innovations, attitudes toward them, adoption or rejection, implementation or resistance to them, and, finally, strengthening of early decisions and behaviors [5].

According to Rogers [5], specific perceived characteristics of technology innovations could make them more or less appealing to the users: relative advantage, compatibility, complexity, trialability, and observability of innovations. In NICU it could make sense to apply this theoretical framework, because it has been already adopted to study the implementation of new practices in different clinical settings [8]. More specifically, within NICU innovations are frequently impeded by users for their high level of complexity, and the consequent difficulty to understand or use them, and low level of trialability, hence, of the degree to which users can implement innovations on a small scale. Furthermore, in NICU we can register low levels of observability, as intended like the level to which the outcomes are visible, easily observed in an overall perspective, and their aim is understood by others, These negative phenomenon could mostly happen in absence of adequate training programs on the matter.

In particular, during the last decade, from the side of the NICU staff, new technologies introduced very complex and advanced systems of direct and remote monitoring and care of infants, in multi-bed or individual rooms, equipped with central control units. This changed the design of work environment and the characteristics of the tasks: recent and significant studies have demonstrated that information and communication technology changes contributed to improve job satisfaction and to reduce job stress of work staff, thanks to a rationalization and clarification in task assignment and higher levels of responsibility, autonomy, participation and specialization of each worker [6]. Overall physical environment, job, technology, and off-the-job quality for the staff would be significantly increased, especially with the adoption of individual rooms, thanks to an higher control on single babies, reduction of noise environment and complaints by the families, even though the operators experienced more difficulties in team interaction sand relevant decline of their quality, respect to the adoption of new technologies in multi-bed rooms [6]. The presence of many bed in one room caused for workers insufficient space to manage and writing clinical sheets, noisy, crowded and disordered working environments [11].[2]

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the service. Level of satisfaction significantly increased for: less than one week recovery, stay in a private room, less critical self-reported conditions at the admission, men gender, family proactive support. As example of a statistical evaluation of patient and family satisfaction, and their socio-demographic characteristics and reported problems about quality of the health service, see also Cleary and colleagues [10].

[2]Smith [6] investigated average perceptions of principal indicators of patient care effectiveness, efficiency and quality of workers of NICU of a US Hospital by a 130 question survey. He observed ergonomic design features and then analyzed task activity of the patient care performance of selected staff, by measuring statistically: quality perception of being NICU worker, level of job satisfaction, level of patient care effectiveness, quality of the work envi-

From the side of parents, numerous studies highlight that higher levels of privacy and better space accommodation for families would reduce complaints and increase their satisfaction and quality perception of the care, above all in individual rooms high technology equipped [6]. The presence of family and newborn supportive procedures as: gentle handling, minimal handling, bonding, rooming-in processes [13]; respected visiting hours, more than open visits [14]; the availability of psychologists which register parents and caregivers aptitudes by a specific check list and speak with them [15], significantly increase family and caregivers satisfaction.

New physiological monitoring data models, called e-Baby architectures, that also allows the care of bush, rural and urban remote babies who needs NICU services (on-demand virtual NICU) [3], have been introduced in last decade with positive effects on care unit staff, family and patients, in terms of efficacy and efficiency of health patient outcomes, job satisfaction, organizational climate and family and infants satisfaction. Main technological innovations, in fact, consist in centralized systems of monitoring cerebral and perfusion levels of infants vital systems and guarantee more physical and psychological safety for staff and families, basing on advanced methods of transmission and cessation of clinical data from babies bed to centralized monitors, with the presence of more comfortable private rooms for less critical infants [16, 17, 18, 19, 20, 21, 22].

In particular, some researchers [20] of the Center of Online Health of Queensland University in Australia, in collaboration with Department of Neonatology and NICU of Brisbane Hospital (Queensland, Australia) and parents of eight ventilated babies, assessed the efficacy of a system for checking newborns via real-time video, called NEMO (Neonatal Examination and Management Online): the collection and transmission of data of 854 tests, relating respiratory rate and perfusion, data from cot-side device, X-ray image, and endotracheal tube placement for the eight ventilated infants, registered more than 90% of liability and efficacy for timely information of clinicians and nurses in spite of the use of ordinary phone mean.

Remote monitoring systems of critical ill newborns conditions have let other significant results in terms of efficacy of monitoring and care, and reduction of mortality and long term disability rates for pre-term and critically ill term infants involved in Bush Babies Broadband project in Australia, which benefitted of the first on-demand virtual NICU architecture in the Region for rural and remote urban areas families [3]. This experiment let the possibility for expert Neonatologists of regional hospitals to receive in real time physiological data and X-ray images by monitors, ventilators and audiovisuals streams attached to babies of remote areas, preventing moving the infants if dangerous for their health, and providing better care by virtual connecting procedures “on demand”, with reduction of health risks and costs [3]. The four main

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ronment, quality of patient care, level of job quality, quality of patient safety, quality of staff safety, quality of patient care team interaction, quality of interaction with patient care technology, quality of life off-the-job, quality of their health. Previously, Tucker and colleagues [2] also investigated psychological safety of NICU staff using Edmondson’s scale [12] and its statements about good feelings for free expression of own skills and talents, free evaluation of others, free communication with colleagues about doubt, and free choose of good problem solving strategies.

components for the Bush Babies Broadband architecture project were based on PC technology, and, in particular, on: personal computer with Web browser software and Internet access for the Bush Babies Remote Station; centralized referral database of available consultants residing within the virtual network and selected by specialty, location and time; computer with Microsoft Windows operating system and Internet access for physician station that let clinicians to have access in any time to static and real-time physiological data and video images of babies; data collection unit with running specialized software connected with medical device monitors and video camera, able to package incoming data in streams transmittable across Internet [22].

Other e-baby architectures also involve NICU control stations, which check the size of the data package elaborated and transmitted by Data Collection Unit via the physiological log web service, and Solution manager Service, located in the hospital NICU server room of reference, for near real time analysis and trend detection [21].

Finally, some Authors [17] studied the efficacy of remote checking of electrical activity of the brain of critically ill newborns, to monitor their neurological conditions though the consultation of trained neurophysiologists to reduce dangerous delays in diagnoses and interventions: a web based remote monitoring system allows experts to receive in near real time an ongoing continually updating view of neurological conditions of infants by simple web-connected PCs with modern browser as Adobe Flash plugin installation (multiple users everywhere sited can independently and simultaneously view data).

Methodology

Data were collected by using a qualitative methodology: the case study. As Benbasat and colleagues [23] claimed, "case methodology is clearly useful when a natural setting or a focus on contemporary events is needed" [23, p. 372]. Based on the case study method, we conducted a qualitative analysis using both interviews and document analysis techniques in order to collect data on the Neonatal Intensive Care Unit (NICU) of two largest public hospitals in Naples (Italy), such as the *AORN Santobono Pausilipon* and the *AORN Azienda Ospedaliera Specialistica dei Colli* (Monaldi, Cotugno, and CTO). During 2014, we realized one interview in each hospital, lasting about three hours each, based on open questions about: the description of the past technology and innovations recently introduced in the hospital NICU, the organizational change effects, the perceptions about resistance to acceptance by families, and the perception of acceptance and adoption attitudes by workers, the scenarios for the future. In particular, semi-structural interviews were conducted with Prof. Carmine Pecoraro and Dr.Annalisa Passariello, respectively director of the NICU of the *AORN Santobono Pausilipon* and manager of the NICU of the *AORN Azienda Ospedaliera Specialistica dei Colli*, in order to analyse the impacts of organizational and technological innovations on physicians, nurses and patient's families. Moreover, we also collected archival data about past and new technologies in the two NICU, and we took free notes about the context, in an ethnographic broader sense.

Results

The NICU of the AORN Santobono Pausilipon

The *AORN Santobono Pausilipon* is one of the biggest children's public hospitals in the Southern of Italy. It was born as Santobono hospital and then have incorporated Pausilipon and Annunziata hospitals. The *AORN Santobono Pausilipon* is composed from 7 departments and 70 units, where about 1.500 people work. Among the 70 units, we focused on the NICU that, in turn, is related to hospital's emergency department. The NICU is composed of 36 hospital beds and about 8 physicians and 28 nurses.

During the last decade, some organizational and technological innovations related to unit layout and new advanced monitoring and care procedures were introduced in this unit, making major changes for workers and families of neonates patients. With refer to organizational innovation, it was realized the Neonatal Center (*Piastra Neonatale*), a structural unit that closes proximity neonatology and neonatal intensive care units on the same floor. This organizational innovation enabled an improvement in the human resource management and medical device usage. Indeed, as director suggested, the Neonatal Center has improved rapidity of clinical interventions in emergency cases thanks to proximity of professionals (physicians and nurses) and medical device. Furthermore, family rooms were built in order to allow neonate and his family to enjoy a private space accommodation after critical ill phases. Family rooms enable parents and caregivers to provide neonate the affective and emotional attention useful for a faster recovery.

With refer to technological innovations, it was installed a control station, allowing physicians and nurses to monitor data collection units situated in close proximity to the beds/humid cribs. It enables the establishment and cessation of the collection of data from the medical devices and also provides a mechanism to control the size of the data package by utilising the physiological log web service to transmit the data to the Solution Manager Service.

According to the director of NICU, these organizational and technological innovations are influencing worker staff unit's job satisfaction and organizational climate. Indeed, thanks to the Neonatal Center clinicians and nurses of neonatology and NICU are located in the close proximity, so enabling a higher interaction and information sharing among them. This leads to increase knowledge and skills of workers, encouraging cooperative behaviour than competitive and thus a higher level of job satisfaction and a positive organizational climate. Furthermore, the director also supposed that innovations could positively affect the family and patient's satisfaction. Indeed, family rooms encourage a better interaction between family and patient in private space perceived as less stressing and more welcoming. Moreover, the interaction with more satisfied operators also increases the level of trust of family and caregivers. These two phenomena lead patients and families towards a higher rate of customer satisfaction.

The NICU of the AORN Azienda Ospedaliera Specialistica dei Colli

The *AORN Azienda Ospedaliera Specialistica dei Colli* is one of the biggest public hospitals in the Southern of Italy. It was born with the merger of three previous hospitals such as the *Aziende Ospedaliere* "V. Monaldi", specialized in pneumonia and cardiovascular system, the *Azienda Ospedaliera* "D. Cotugno", specialized in infectious diseases and hepatology, and the *Presidio ospedaliero* C.T.O. (*Centro Traumatologico Ortopedico*), specialized in orthopaedics and rehabilitation. The *AORN Azienda Ospedaliera Specialistica dei Colli* is composed from 11 departments and 94 units, where about 2.120 people work. Of the 94 units, we focused on the NICU that, in turn, is related to the *Dipartimento di area critica*. The NICU is composed of 17 hospital beds and 8 physicians and 1 clinical director, and hospitalized about 300 patients per year.

Until last year, a physician specialised in neuropsychiatry performs electroencephalograms on newborn aimed to monitor and recording brain activity and manages relationships with patients' families and caregivers. Then, the NICU has decided to improve the monitoring systems by adopting two new technologies such as Cerebral Function Monitoring (CFM), a new scoring system for the evaluation of brain maturation in neonates, and Near-Infrared Spectroscopy (NIRS), a spectroscopic method used to monitor brain activity by identifying and measuring changes in the concentrations of oxygenated and deoxygenated haemoglobin in heart and lungs. In particular, 4 CFM and 6 NIRS technologies are now performing the monitoring and recording of newborn brain activity with the physicians and nurses support, so replacing the neuropsychiatry work. Although the CFM and NIRS usage is mandatory, the training has been done on clinicians and nurses for CFM systems only producing critical problems on the acceptance and use of technology. Indeed, as NICU's manager suggested, the training lack does not let care unit staff to perceive the usefulness and ease of use of technology used. Moreover, the absence of medical and technological operational guidelines do not encourage the workers availability to technology acceptance and use.

These issues have caused an increased workload of care staff unit and a disoriented and confused climate due to the absence of an experienced and skilled worker able to support colleagues for problem solving and to manage families complaints and stress. In this regard, new technologies adopted have caused organizational issues in term of job design and perception of organizational support, negatively affecting job satisfaction and organizational climate.

Moreover, the use of CFM and NIRS with related multiple electrodes, above all for less critical emergency patients, and the absence of family and patient guidelines encourage high level of anxiety and stress of caregivers prompting them in vain to seek support to disoriented operators. This issue negatively influences the customer satisfaction and further burdens the organizational climate.

Discussion

The aim of this study was to investigate the effects of innovation technology on organization, workers and patients' families within NICU. These effects were analysed by the perspective of two NICU's directors, such as *Santobono Pausilipon* (A) and *Azienda Ospedaliera Specialistica dei Colli* (B), who explaining the changes on organizational asset and job design, as well as on patients and families attitudes and behaviours, when new technology occur.

In particular, with reference to organizational and workers effects, the NICUs directors said that:

> A. "We expect a progressive reduction of conflict among unit staff members, in reason of the cooperation on the same floor of nurses, neonatologist and others health care workers, in the past located on different floor, which have been involved in job rotation programs, thanks to new technology, to optimize the use of human and financial resources".
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> B. "There are no written documents about he purpose of the adoption of new techonologies in NICU and their implementation is prescribed in a mandatory way; consequently, nurses and physicians show disorientation and dissatisfaction, in absence of adequate information meetings".

With reference to patients and families attitudes and behaviours effects, the NICUs directors underlined that:

> A. "Many improvements in health status of babies have been registered thanks to the adoption of a centralized monitoring station in the centre of NICU environment and to the introduction of an operating room within neonatal intensive care unit, which avoid the transfer of babies on another floor of the hospital, if they need urgent surgery intervention".
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> B. "New advanced medical monitors and image device allow a better care of the babies and allow the NICU to remain a center of excellence in Southern Italy, preserving past prestige".
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> A. "Customer satisfaction and reduction of claims will be surely developed in reason of the architectural features of the context, renewed to improve positive reactions of the families, the reduction of conflict among nurses which finally works on the same floor, and the presence of Family rooms dedicated to parents and their babies which need long-term care".
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> B. "New technologies frequently are physically invasive for the babies, and they can cause the increase of level of anxiety of families, questions and claims, specially in presence of high level of education of patients' families".

Therefore, in agreement with the recent literature on technological and organizational changes within NICUs, the results have shown some positive changes in the level of conflict within unit staff, only for more participative technological changes well supported by trainings (case A). Furthermore, the significant improvement of health of babies and reduction of mortality rate, reported for both cases, could be attributed to new remote medical devices and innovative control systems for each bedside. Finally, positive changes in patients' families attitudes and behaviours has

been registered only for one case (A) thanks to major attention paid by organization to architectural features and culture of willingness to listen and interaction.

Conclusions and limitations

This paper reports on an exploratory study of NICU directors' perceptions of organizational and behavioral changes, and workers and patients' families reactions arising from organizational and technology innovations adoption. Based on the case study method, we conducted a qualitative analysis for collecting data on the NICU of two Southern Italian hospitals. Results have shown that, from the point of vies of NICU directors, health care workers and patients' families positively perceive the changes when both organizational and technological innovations occur. On the contrary, when organizational changes do not follow the technological ones, health care workers and patients' families are more stressed.

Table 2 summarizes the conclusions of our study.

Table 2 The impact of innovations on NICUs

		Innovation		**Impact**	
		Organizational innovations	*Technological innovations*	*Perceived Health care workers impacts*	*Perceived Family and patient impacts*
NICUs directors	*Santobono Pausilipon*	Yes	Yes	Positive	Negative
	Azienda Ospedaliera Specialistica dei Colli	No	Yes	Negative	Negative

This paper has several limitations. First of all, data collection reported in this paper concerns just two semi-structural interviews and some document analysis. We intend to conduct other interviews to the NICU's physicians, nurses and patients' families of the two hospitals which could give greater depth to our research. Second, the impacts of innovations on workers and patients' families were indirectly collected by interviewing NICU's clinicians rather than all the workers of the unit and patients' kin directly involved in the process. Interviews to workers and babies' families and the content analysis of their missives to the hospital after discharge will move in this way, in order to enable us to better understand and describe managerial implications.

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