Author	Title	Year	Country	Primary study objectives
Bång & Timpka [25]	Cognitive tools in medical teamwork: the spatial arrangement of patient records	2003	Sweden	To "build an understanding of the roles physical artifacts like paper-based patient records play in supporting cognition and collaboration in health care settinge" (as a preliminary step towards using human systems design to construct computer-based patient records.)
Berndt, Furniss & Blandford [26]	Learning contextual inquiry and distributed cognition: a case study on technology use in anaesthesia	2015	England	"To understand the interactions of anaesthetists, how the design of procedures and the environment supports work, and particularly how they used infusion devices…"
Cohen et al. [10]	A cognitive blueprint of collaboration in context: distributed cognition in the psychiatric emergency department	2006	USA	"To characterize the DCog that underlies patient care in a psychiatric emergency department in order to enhance the understanding of error in this context."
Collins et al. [27]	Model development for EHR interdisciplinary information exchange of ICU common goals	2011	USA	To categorize the types of communication and information activities that occur, and develop a theoretical model for interdisciplinary communication of ICU common goals in the context of EHR use.

Collins et al. [28]	Clinician preferences for verbal communication compared to EHR documentation in the ICU	2011	USA	To describe the ICU activity system in the context of interdisciplinary communication of common goals; and to describe nurses' and physicians' perceptions of communication of common goals in the ICU.
Collins et al. [29]	In search of common ground in handoff documentation in an Intensive Care Unit	2012	USA	To analyze structure, functionality, and content of nurses' and physicians' handoff artifacts to inform the development of a handoff tool to support communication and coordination of care through integration with the EHR in a multi-disciplinary and highly specialized ICU setting.
Dias et al. [30]	Dissecting cardiac surgery: A video-based recall protocol to elucidate team cognitive processes in the operating room	2021	USA	To elucidate the cognitive processes involved in surgical procedures from the perspective of different team roles; To provide a comprehensive compilation of intraoperative decision points, critical communications, pitfalls, problem-solving/ prevention strategies, and cognitive demands related to surgery; To present this comprehensive analysis in an interactive analytics dashboard.
Furniss et al. [31]	Exploring medical device design and use through layers of distributed cognition: how a glucometer is coupled with its context	2015	England	"To investigate the design and use of a modern inpatient glucometer, and how it is coupled with its context."

Furniss et al. [32]	Exploring structure, agency and performance variability in everyday safety: An ethnographic study of practices around infusion devices using distributed cognition	2019	England	To investigate how safety is constructed and compromised around infusions on a hematology ward, and to describe the socio-technical system in which infusion practice is organised & embedded.
Furniss, Franklin & Blanford [33]	The devil is in the detail: How a closed-loop documentation system for IV infusion administration contributes to and compromises patient safety	2019	England	To gain an in-depth understanding of patterns of work that evolved in an ICU where a closed-loop IV medication administration system was implemented and of the consequent effects on patient safety.
Gilardi, Guglielmetti, Pravettoni [34]	Interprofessional team dynamics and information flow management in emergency departments	2014	Italy	To consider the critical aspects of collaborative teamwork in EDs that may have an impact on information flow...specifically, how ED team members gather, transfer and integrate patient-specific information and how technological artifacts assist information flow.
Grundgeiger et al. [35]	Distributed prospective memory: An approach to understanding how nurses remember tasks	2009	Australia	"The goals of the study were to capture prospective memory (PM) tasks performed by ICU nurses, to classify the PM tasks using the taxonomy developed by Dismukes and Nowinski, and to investigate the extent to which the support for PM tasks was distributed..."

Grundgeiger & Sanderson [12]	Interruption management in the intensive care unit: Predicting resumption times and assessing distributed support	2010	Australia	To test whether prospective memory theory can be used to study interruptions. To investigate which predictors help us understand the effects of interruptions in ICU nursing. To address the mismatch between healthcare interruption and lab studies in terms of the disruptive effects of interruptions.
Hakimzada et al. [36]	The nature and occurrence of registration errors in the emergency department	2008	USA	To characterize the factors that compromise patient safety at the point of patient registration in the ED
Hazlehurst et al. [37]	How the ICU follows orders: care delivery as a complex activity system	2003	USA	To shed light on how the ICU as activity system implements an order process and discuss what it may mean for the design or introduction of automated information systems such as computerized physician order entry."
Hazlehurst, McMullen, & Gorman [38]	Getting the right tools for the job: Distributed planning in cardiac surgery	2004	USA	To describe how cognitive and material resources in the activity system of the OR enable well-defined courses of action (through preparatory configuration) while dynamically accommodating unlikely events (through replanning).

Hazlehurst, McMullen, & Gorman [11]	Distributed cognition in the heart room: how situation awareness arises from coordinated communications during cardiac surgery	2007	USA	To explore how achieving the goals of open-heart surgery requires coordination among team members and between the actors and the tools and technologies that support their work. To uncover the means by which this coordination produces situation awareness as a natural byproduct.
Hussain, Dewey, & Weibel [39]	Mitigating medical alarm fatigue with cognitive heuristics	2016	USA	To "explore fast and frugal heuristics that may be used to prioritize patient alarms, while continuing to monitor patient physiological state."
Hussain & Weibel [40]	Can DiCoT improve infection control? A distributed cognition study of information flow in intensive care	2016	USA	To describe how DiCoT principles led us to solutions to improving information flow in critical care. To study patient isolation procedures & discuss alternative solutions to improving information flow based on an analysis of the ICU system using Dcog.
Jensen & Bossen [41]	Distributed plot-making: Creating overview via paper-based and electronic patient records	2016	Denmark	To highlight distinct and similar features of paper based and electronic paper records and to explore how these features support or hinder the establishment of clinical overview.

Kannampallil et al. [42]	Understanding the nature of information seeking behavior in critical care: Implications for the design of health information technology	2013	USA	"To characterize the nature of physicians' information seeking process, and the content and structure of clinical information retrieved during this process."
Liberati et al. [43]	How to be a very safe maternity unit: An ethnographic study	2019	England	"To characterise what makes [a specific maternity unit] safe, attending both to features of context and intervention to generate an in depth understanding."
Lin, Chaboyer, & Wallis [44]	Understanding the distributed cognitive processes of intensive care patient discharge	2014	Australia	"To better understand and identify vulnerabilities and risks in the ICU patient discharge process, which provides evidence for service improvement."
Mamykina et al. [45]	Driven to distraction: The nature and apparent purpose of interruptions in critical care and implications for HIT	2017	USA	"To examine the apparent purpose of interruptions in a Pediatric Intensive Care Unit and opportunities to reduce their burden with informatics solutions."

McLane & Turley [46]	One Size Does Not Fit All: EHR Clinical Summary Design Requirements for Nurses	2012	USA	To "establish baseline functional requirements for an EHR-generated patient summary."
Mylopoulos & Farhat [47]	"I can do better": exploring purposeful improvement in daily clinical work	2015	Canada	To "identify and elaborate [on] distributed cognitive processes that occur when an individual enacts purposeful improvements in a clinical context."
Nemeth et al. [48]	Discovering healthcare cognition: The use of cognitive artifacts to reveal cognitive work	2006	USA	To describe the use of cognitive artifacts in healthcare and to consider implications for patient safety. To develop and use descriptive models of actual behavior and to examine how practitioner cognition can be understood using the analysis of cognitive artifacts to understand it.
Nemeth et al. [49]	Before I forget: How clinicians cope with uncertainty through ICU sign-outs	2006	USA	To "show that clinicians manage transitions between shifts using verbal hand-offs, or “sign outs,” to coordinate clinical work, authority, and responsibility."
Nemeth et al. [50]	Revealing ICU cognitive work through naturalistic decision-making methods	2016	USA	To "describe the process that our team and client followed to reveal the cognitive work in a burn intensive care unit (BICU) and to support it by developing an ecologically valid, coherent information technology (IT) system to facilitate individual and team decisions."

Parush et al. [51]	The use of resources during shift hand-offs in a pediatric intensive care unit	2010	Canada	To determine the type of resources used and the frequency of their use during nursing handoffs.
Pelayo et al. [52]	Applying a human factors engineering approach to healthcare IT applications: example of a medication CPOE project	2009	France	To explore medication administration in the context of a Computerized Provider Entry Order system, with a focus on the distribution of tasks among actors of the system. To use organizational analysis to describe variations in distribution of tasks between the actors of the medication use process, depending on the organization of the work system."
Rajkomar & Blandford [53]	Understanding infusion administration in the ICU through distributed cognition	2012	England	To improve understanding of the situated use of infusion pumps, which could help improve the safety and usability of the devices, while testing the utility and practicality of applying DiCoT to the study of a socio-technical healthcare system such as the ICU.
Sarcevic, Marsic, & Burd [54]	Teamwork errors in trauma resuscitation	2012	USA	To understand the causes of human errors unique to teamwork during trauma resuscitation.
Turki, Bosua & Kurnia [55]	Exploring the use of EPR as a cognitive artefact for nursing handover	2014	Australia	"To investigate the effects of using Electronic Patient Record (EPR) as a cognitive artefact for nursing handover."

Wilson, Galliers & Fone [56]	Cognitive artifacts in support of medical shift handover: An in use, in situ evaluation	2007	England	"To present an argument for the importance of in use, in situ evaluation and to identify the kinds of use issues that can be revealed in such an evaluation as a step toward developing techniques that can be readily utilized by practitioners."
Xiao et al. [57]	Cognitive properties of a whiteboard: A case study in a trauma centre	2001	USA	To study a public display board in an OR in a trauma center where coordination needs are exacerbated by unpredictability of incoming patients. To understand existing display boards, so that the development of technology can be guided by our understanding of the role these displays have in supporting collaborative work.
Xiao et al. [58]	Three perspectives of rounds: Choreographing information flow in an intensive care unit	2008	USA	To "adopt three perspectives in advancing our understanding of communication during rounds and in devising interventions: DCog, computer-supported cooperative work, and common ground."

Setting	Healthcare professionals	Artifacts studied	Interactions discussed
ED	Physician, nurse, nurse's aide	Paper health/ medical charts, patient tracking cards/stickers, desk in shared workspace	Provider - Artifact
OR	Physician, resident, OR techs	OR equipment (infusion devices, monitors, ventilators), telephones	Provider - Provider Provider - Artifact Patient - Provider Patient - Artifact
ED	Physician, resident, social worker, nurse, substance abuse counselor	Whiteboards, patient charts, nursing notes, admissions notes, discharge notes, legal documents	Provider - Provider Provider - Artifact Patient - Provider
ICU	Physician, fellow, resident, nurse, pharmacist, medical student, nursing student	EHR, paper health/ medical charts	Provider - Provider Provider - Artifact

ICU	Physician, resident, nurse, pharmacist, medical students, social worker, respiratory therapist, nutritionists	Personal notes, "to do" lists, EHR, paper health/ medical charts, pagers	Provider - Provider Provider - Artifact
ICU	Resident, physician assistant, nurse	Handoff Documents	Provider - Provider Provider - Artifact
OR	Physician, perfusionist	OR equipment, checklists	Provider - Provider
Inpatient hospital unit	Biochemist, healthcare assistant/ nurse's aide, nurse practitioner, nurse	Glucometer and it's docking station, supply kit, trolley with supporting equipment, computers, paper health/ medical charts	Provider - Provider Provider - Artifact Patient - Provider Patient - Artifact

Inpatient hospital unit	Nurse practitioner/ nurse, healthcare assistant/ nurse's aide	Paper health/ medical charts, medication administration systems	Provider - Provider Provider - Artifact Patient - Provider
ICU	Physician, nurse	EHR, patient track boards, medication administration systems linked to the electronic prescribing system	Provider - Provider Provider - Artifact Patient - Provider Patient - Artifact
ED	Triagist, physician, nurse practitioner, nurse	Computers, checklists (electronic)	Provider - Provider Provider - Artifact
ICU	Nurse practitioner, nurse	Personal notes to aid memory of tasks to complete, vital sign monitoring systems and alarms, medication administration systems, computers	Provider - Provider Provider - Artifact

ICU	Nurse practitioner/ nurse	Personal notes, vital sign monitoring equipment/ ventilators, patient monitoring alarm systems, medication administration systems, EHR	Provider - Provider Provider - Artifact
ED	ED registration clerk, physician, resident, EMT/ paramedics	EHR, patient ID wristbands, computers, telephones, pagers, paper health/ medical charts	Provider - Artifact Patient - Provider Patient - Artifact
ICU	Physician, nurse	EHR, paper health/ medical charts, medication administration systems	Provider - Provider Provider - Artifact Patient - Provider
OR	Perfusionist, physician, physician assistant, nurse, OR Tech	OR Equipment (heart-lung machine, ventilator), checklists (tool/ instrument cheat sheets, inventory lists)	Provider - Provider Provider - Artifact

OR	Perfusionist, physician	OR Equipment (heart-lung machine, ventilator, table of OR surgical equipment)	Provider - Provider Provider - Artifact
ICU	Nurse	Medication administration system, ventilator, drips, medication administration sheets	Provider - Artifact Patient - Provider
ICU	Physician, nurse, pharmacist/ pharmacy tech, unit manager, patient care assistants, respiratory therapist,	EHR, telephones, pagers, computers, isolation signs, masks	Provider - Artifact
Inpatient Hospital Unit	Physician	Personal notes, EHR, paper health/ medical charts	Provider - Artifact

ICU	Physician, fellow, resident	EHR, paper health/ medical charts, computers	Provider - Provider Provider - Artifact
Inpatient Hospital Unit	Physician, resident, midwives, risk managers	Whiteboards, maternity unit dashboard	Provider - Provider Provider - Artifact
ICU	Physician, resident, nurse, registrar, ward medical staff, ward clerk, bed manager	EHR, computers, computerized hospital bed management program, discharge summaries	Provider - Provider Provider - Artifact
ICU	Physician, resident, physician assistant/ nurse practitioner, nurse	EHR, pagers, telephone, patient monitoring equipment	Provider - Provider Provider - Artifact Patient - Provider

Inpatient Hospital Unit	Nurse	EHR, paper health/ medical charts, personally created cognitive artifact	Provider - Artifact
OR	Physician, resident, fellow, nurse/ nurse practitioner, OR tech	OR equipment	Provider - Provider Provider - Artifact
OR	Physician, resident, certified registered nurse anesthetist (CRNA), anesthesia coordinator, nurse, nurse coordinator	Schedules, OR graph (all paper-based), patient track boards, whiteboards	Provider - Provider Provider - Artifact
ICU	Fellow	Handoff documents	Provider - Provider
ICU	Physician, resident, nurse, physical therapist/ occupational therapist, respiratory therapist	EHR, telephones, email, handoff documents, daily wound care plan (paper), vital signs printout (paper), charge nurse checklist (paper); wound tracking, fluid resucitation & nutrition management software	Provider - Provider Provider - Artifact

ICU	Nurse	Paper health/ medical charts, handoff documents	Provider - Provider Provider - Artifact
Inpatient Hospital Unit	Nurse practitioner/ nurse, physician, pharmacist/ pharmacy tech	Paper health/ medical charts, medication administration systems	Provider - Provider Provider - Artifact Patient - Provider
ICU	Physician, nurse, medical assistant, medical physicist	EHR, medication administration systems, computers	Provider - Provider Provider - Artifact Patient - Provider
ED	Physician, resident physician, nurse	EHR, OR equipment, checklists, whiteboards	Provider - Provider Provider - Artifact
ICU, ED	Nurse	EHR, paper health/ medical charts, handoff documents	Provider - Provider Provider - Artifact

Inpatient Hospital Unit	Physician, resident	Paper health/ medical charts, whiteboards, handoff documents, computers	Provider - Provider Provider - Artifact
OR	Physician, nurse, OR tech	Whiteboards, patient call strip	Provider - Artifact
ICU	Physician, resident, medical student, physician assistant/ nurse practitioner	EHR, paper health/ medical charts, computers, pre-rounding sheet	Provider - Provider Provider - Artifact

Interactions detailed	Type of study	Research methods
Placement of patient charts on a shared desk facilitated non-verbal, bidirectional communication amongst team members. Charts were laid out in 2 columns. A head nurse triaged patients and placed charts according to acuity level in the right column to signal the physician who was to be seen next. After evaluating a patient the physician moved the chart to the top left column to signal the nurse to take action. After the nurse took action, they would move the chart to the bottom left column. When new results (e.g., labs, X-Rays) became available the nurse would place the findings on top of the chart for physician review. Stickers and position tags were used to signal if patients moved temporarily (e.g., to radiology).	Qualitative	Observations, Artifact Analysis
Interactions between anesthetists and OR techs were "high bandwidth". The OR tech prepared equipment and liaisoned with external devices and resources (e.g., phones), making them a key connector to environmental artifacts. Interactions between surgeons and anesthetists were bidirectional but "restricted," as they occur across a surgical barrier. Masks were noted as an added barrier to information flow. Interactions between anesthetists, monitors, and infusion pumps were described. Anesthestists rely on monitors as "information hubs" that tell them how the patient is doing. Interactions between anesthetists, monitors and infusion devices were "not optimal" and impacted by a cumbersome set-up in which "higher pumps obscure lower pumps, affecting the user's horizon of observation. Anesthetists were viewed as "information hubs" as they "integrate information from surgeons and monitors. Information also flowed from the patient (who was viewed in the OR as an artifact) to the surgeons and anesthetists. The triad between patient, devices, and anesthetists is key.	Qualitative	Observations, Interviews
Interactions centered around gathering information, communicating verbally and through artifacts, and taking action (stabilization, medication administration, certification, admission/discharge). Information flow between mini-team members, patients, family and external providers (e.g., receiving physician) were described. Handoffs were unstructured interactions (where artifacts were not routinely used). Information from internal representations (i.e., in the mind of clinicians) were noted to be lost at handoff.	Qualitative	Observations, Interviews
Interactions involved 6 categories of information exchange: (1) "Directing an action that seeks to transition the activity system to a new state." (2) "Sharing goals about an expectation of a desired future state." (3) "Conveying shared understanding about the status of the current state." (4) "Alerting about abnormal or surprising information about the current state." (5) "Explaining a rationale for the current state." (6) "Reasoning to solve problems and understand the current state of the system." **Information exchange via the EHR only facilitated 3 of these (1,2,4). Verbal discussions facilitated all 6.*	Qualitative	Observations, Interviews, Focus Groups, Artifact Analysis

Interactions delineated in Table 1: Nurse report (night to day shift handovers on individual patients 15-30 minutes); Resident sign out (night to day shift resident, 15-30 minutes, all of a residents patients); ICU multidisciplinary morning rounds (3-4.5 hrs, all patients); Updates (unplanned, anytime, brief; Neurosurgery rounds (NS attending, resident, neurology attending and fellow, charge nurse, 10-15 min, all ICU patients); Charge nurse rounds (charge nurse and nurse for each patient, 1 min each); Disposition rounds (charge nurse, social work, neurology fellow, 15-30 minutes, all ICU patients); Medical rounds (neurology attending, fellow and residents, 30 minutes, all ICU patients).	Qualitative	Observations, Interviews, Focus Groups
The handoff process "consisted of a conversation between the clinician from the previous shift (i.e., outgoing clinician) and the clinician from the next shift (i.e., oncoming clinician) and was supported primarily by paper-based artifacts (including print-outs of the resident/PA computer-based handoff tool) and occasionally by reference to the EHR or other patient care monitors or devices when needed." Nurse-nurse, resident-PA handoffs occurred at the change of shift, twice daily.	Qualitative	Artifact Analysis
Interactions between anesthesiologists, perfusionists and cardiac surgeons were explored and documented based on the 14 identified steps in the procedure, and the 4 categories into which they were allocated (decisions, critical communications, pitfalls, strategies).	Mixed Methods	Interviews, Cognitive Task Analysis
"Following DiCoT's concentric layer (DiCoT-CL) framework...we identify different layers within the sociotechnical system that surrounds the glucometer. This shows how cognition is distributed, and how sociotechnical dependencies and couplings reveal themselves in the basic mechanics of the system, through the coordination of different artifacts, people, tasks, physical spaces and periods of time": 1) The artifact model explained how the glucometer interacted with it's various supporting components; 2) The social model explained the interactions between healthcare assistants, nurses, and patients that were facilitated by the glucometer (taking patient readings, communicating results to patients, healthcare assistant communicates abnormal results to nurse). Additionally, this model captures the more distant interactions between the glucometer and the diabetes specialist and biochemist, who monitor results from afar (i.e. via a central database) for QI purposes. 3) The information flow model describes the movement of information in the system.	Qualitative	Observations, Interviews

Interactions were referred to as occuring at micro, meso, and macro levels; however, it was noted that the 'boundaries between layers were not always found to be clear": "The micro layer generally refers to a single nurse with the patient at the bedside focused directly on the infusion task." "The meso layer generally refers to interactions at the ward level (e.g. between two different professionals) or other activities that are beyond the infusion task itself". "The macro layer refers to interactions at the hospital level or higher"	Qualitative	Observations, Interviews
Physician handoff (referred to as "doctors' sensemaking") happens in the morning at the central doctors' hub. An overview screen (a shared artifact)provides a summary of the ward/patient statuses. The night shift doctor gives a patient by patient overview to the day shift doctor, and the day shift doctor then develops a tentative plan with help from his/her team. "Blue slips" that summarize each patients plan are provided to nurses to help with coordination on AM rounds. Interactions between nurses, the EMPA, and infusion pumps were described: The nurse collects materials/drugs, gets a double check from a colleague, then administers the drug. If the smart pump had an appropriate drug library entry used correctly, additional external checks were introduced by that. When the nurse sets up an infusion, they also need to 'map' the pump to the patient's EPMA record. If the pumps are mapped to the patient's EPMA record correctly, the EPMA system monitors what the pumps are doing in terms of the rate, volume and any bolus doses."	Qualitative	Observations, Interviews
The triagist completes a computerized checklist and assigns an emergency code. The triagist serves as a highlighter of key information. The physician views some or all the documented report (depending on if they open one or two screens). The triagist or physician could call each other or leave their area to directly communicate if additional information was needed or if critical information needed to be shared that was not appropriate for the written chart. A nurse-physician pair manages multiple patients. The nurse helps search for and highlight information (e.g., lab arrival) for physicians, acts as memory keeper and process organizer to ensure information flow, support decision-making and help overcome some of the challenges of the EHR.	Qualitative	Observations, Interviews
Interactions occurred between bedside nurses, bay nurses, physicians, and the personal notes and ICU equipment that supported their work. These were extensively described in terms of how prospective memory was distributed (temporally, spatially, both) within the work environment, and how external representations of prospective memory tasks were used to support work.	Qualitative	Observations, Artifact Analysis

This article focused on "distractions" which were "defined as a visual or auditory event that observably captured the attention of the participant and delivered some information." These distractions could be caused by people (doctors, other nurses, other staff) or artifacts (equipment alarms) and result in ackowledgements (short oral or visual acceptance of the distraction without primary task discontinuity); multitasking (continuous work on both the primary and the distracting task); or interrupting (“hands off” cessation of the primary task)	Mixed Methods	Interviews, Eye movement tracking, Observations
Retrieval of patient data at registration: "Most often the information is provided by the patient directly. When the patient cannot provide information, it is obtained through a third party - a relative/ caretaker or EMS personnel." The registration clerk interacts with the computer/ computer system to input information required for proper identification. "The computer system is designed to run the patient information against the hospital database to find if the patient has any previous records. If no matching information is found, the patient is given a new record number and is registered as a new patient. Once registration data is entered, ED registration procedure dictates that the information is read back to the patient and the patient is asked to confirm the information." This latter part of the process involves simultaneous interactions between registration clerk, patient, and computer system. The registration clerk imprints the paper ED chart with the patient’s information and creates a wristband. The registration clerk must return to the patient, reconfirm his identity and apply the wristband.	Qualitative	Observations, Interviews
"Orders are created by a physician (Step 1) and are then carried out by the responsible nurse or care team (Step 2)" "The unit secretary performs the function of “pulling orders” from the patient." The unit secretary "expands upon" orders and also acts to "repair" information if she notices inconsistencies.	Qualitative	Observations, Interviews, Artifact Analysis
Surgeons are responsible for collaborating with the PA and scrub techs to perform manipulations of the heart; collaborating with the anesthesiologist to monitor and manage hemodynamic status; coordinating the cardiopulmonary bypass process with the perfusionist; informing the entire OR team about certain key stages in the procedure; requesting changes in settings on various machines; and requesting tools from techs. Techs’ activities are organized around elaborate setup work (preparatory configuration), employing various cognitive artifacts, such as “cheat sheets”, inventory lists, and a standardized layout of tools.	Qualitative	Observations, Artifact Analysis

"Perfusion activities of a cardiac surgery team primarily involve the surgeon and a member of the team called the ‘‘perfusionist.’’ The perfusionist physically controls the heart–lung bypass machine...the surgeon is primarily focused on manual manipulations of the patient’s chest and heart." "Communication between surgeon and perfusionist serves to coordinate the joint activity of cardioplegia management." "Throughout a procedure, surgeon and perfusionist each have only partial access to the information that is relevant to a successful outcome. Furthermore, each must perform distinct actions, requiring distinct areas of expertise, yet these actions must be coordinated in order to achieve shared goals for the surgery." "Coordination in the heart room is accomplished through the appropriate sequencing of actions. This sequencing accomplishes tasks required to achieve goals. Sequencing allows actors to establish the meanings of events (often through reading each others’ actions) and thereby to understand the urgency (and appropriate recovery methods) that pertains when deviations from expected events occur. That is, this organization to the activity yields robust system properties and gives rise to situation awareness."	Qualitative	Observations, Artifact Analysis
Nurses and monitors, nurses and patients.	Mixed Methods	Observations, Interviews, Questionnaires/ Surveys
Interactions among staff and the EHR are critical for denoting the isolation status of a patient. Staff can enter isolation status manually, or be prompted to do so if: "(1) a user places an order to the lab for a specimen to be tested for a suspected contagion, or (2) the patient has a history of harboring a particular contagion." The mask is the key artifact with which staff interact to signal patient isolation status. However, this is absent in cases of contact isolation, leaving staff to view isolation status from: (1) the central work station computer that lists the isolation status of patients or (2) the patient banner in the EHR of individual patients.	Mixed Methods	Observations, Interviews, Artifact Analysis
The first coherent narrative about the patient is produced on personal notes. The notes serve as an initial narrative created before the official version entered into the record. "When going through a paper record to create overview of a case, the physicians could mark pages or highlight sections. In this way, physicians could go through a large amount of information marking what seemed important and relevant and subsequently extract this information while they were creating a clinical overview." "When the staff at the ward used the paper-based record, test results, diagnostic imaging and outside records were printed and placed on the cover of the record visible to the first physician to handle the case. The paper sheets on the cover served as a reminder of test results the physicians were awaiting. When using the EHR, the physicians received no notification when a description of, for example, a CT was available, which meant that they had to actively look for it in the system, and they had to remember that it was necessary to look for it."	Qualitative	Observations, Interviews

"Information was distributed among various sources: paper and electronic records, monitors, and people (nurses, pharmacists, respiratory therapists, and residents)." "During their information seeking process, physicians gathered information from paper charts, electronic records, through patient evaluation, and indirectly, from other clinicians involved in the care process." "Electronic records were often used in conjunction with the paper charts to “fill-in” information that is often unavailable or missing in the paper charts...We observed that the physicians sometimes switched back and forth between paper and electronic charts to find some pertinent information regarding a patient condition (or status)." "Physicians also interacted with clinical support staff including fellows, residents, nurses, and respiratory therapists to update their knowledge about the patient’s current condition."	Mixed Methods	Observations
Interactions were described as highly collegial and focused on building a culture of "psychological safety." Team members were encouraged to speak up if they saw safety concerns, and a system of interpersonal accountability was established among staff. A sense of belongness was cultivated. Handovers, briefings, and safety checks were routinely held and "taken seriously" to maintain a culture of safety. "The work of monitoring, coordination, and response was aided by the unit's whiteboard, which was constantly updated to provide accurate information on labouring women as well as general safety information. Located in the multidisciplinary staff room, members of staff congregated around it frequently, both formally during the twice-daily structured handovers and informally throughout work shifts and breaks."	Qualitative	Observations, Interviews, Focus Groups
"Ward nurses rarely referred to the ICU nursing discharge summary. This appears to be related to its design issues, different understandings of what information should be included and the lack of tool evaluation and improvement over time." "On a small number of wards which had a standardised form to document ICU nursing handovers, the information was transferred better than the wards without such documentation. The form used by ward staff to document phone handover facilitated the handover not just by documenting information; it also provided the ward nurses with a guide, which prompted them to ask questions during handovers."	Qualitative	Observations, Interviews, Artifact Analysis
Interactions among staff and patients were described with a focus on the nature of interruptions among these actors in the system: "Both nurses and MDs were interrupted more frequently by other clinicians in the unit (42.2% for nurses and 44.1% for residents) than by other members of their patient care teams (24.2% for nurses, 37.8% for residents). A considerable number of interruptions for nurses originated from patients and their families (7.3%); in contrast, we captured only a few interruptions of this nature for residents (0.7%). Similarly, nurses were more likely to be interrupted by device alarms (Device Alarms, 8% for nurses, 0.4% for residents), by external clinical sources (9.7% for nurses, 3.3% for residents), and by non-clinical sources (2.8% for nurses, 0 for residents) than were residents. In contrast, residents received numerous interruptions via phone and pager (13.7%); these interruptions were less frequent for nurses (5.9%)."	Mixed Methods	Observations

Internal representations primarily consist of the nurses baseline knowledge, while external representations consist of labs/imaging/other reports from which the nurses gather data. These are used to build and iteratively revise their Personally Created Cognitive Artifacts (PCCAT).	Qualitative	Observations, Interviews, Other (Clinical Scenarios)
Minimally invasive surgery practitioner working with 13 surgical teams including fellows and scrub nurses. Teaching among attending and resident physicians; Preoperative meetings to discuss and plan cases for the upcoming week; The surgeons planned with nursing staff for nuanced set-up of OR equipment.	Qualitative	Observations, Interviews
The Anesthesia Coordinator (AC) and Nurse Coordinator (NC) plan and execute a daily schedule, aiming to "balance the demand" with available resources. Anesthesia assignments are transcribed to the OR Board, which serves as a platform for tracking negotitation, tradeoff decisions, planning, and replanning. Surgical and anesthesia staff coordinate with the AC/NC at the start, during, and at the end of the procedure. The NC notes the completion of a case on the master schedule, and the AC erases it from the OR board.	Qualitative	Observations, Interviews, Artifact Analysis
Handoffs occurred at AM and PM shift change between one off-going and one on-coming physician	Qualitative	Observations, Conversational analysis
Care providers must collaborate over time to make effective decisions, develop treatment plans, assess patient progress, and refine plans to manage care. Through these daily tasks, they demonstrate the macrocognitive aspects of work (naturalistic decision making, sense making/ situation assessment, planning, adaptation/ replanning, problem detection/ coordination/ developing mental models, mental simulation and storyboarding, maintaining common ground, managing uncertainty and risk, turning leverage points into courses of action, managing attention). Information sources, the individuals that used them, and the broader categories (communication, paper, computer, computer and paper) within which each artifact fell were all mapped.	Qualitative	Observations, Interviews, Questionnaires/ Surveys, Artifact Analysis

Nurse to nurse dyads at handoff using artifacts (patient chart, charge note, Kardex, critical care flow sheet, and personal notes) to facilitate information exchange.	Mixed Methods	Observations
Figure 1 outlines the distribution of tasks and the interactions among nurses, pharmacists, physicians, and artifacts: The physician and nurse work collectively to gather information from the patient. The physician then review's the patient's information in the chart, makes a decision, writes an order for the nurse or directly dictates one to him/him, and signs off on it. Nurses send orders to the pharmacist, who retrieves and analyzes the list of orders prior to filling medicationrequests and sending the requested medication back to the nurse. Nurses then prepare and administer the medication, and are required to document it in the medication administration record afterwards.	Qualitative	Observations, Interviews, Artifact Analysis
The System Activity Model (Figure 2) "elaborates on the activity of infusion administration and describes other activities that potentially influence it." The Social Structures Model (Figure 3) outlines "A hierarchical structure that can map to a goal structure such that superordinates and subordinates share responsibility to ensure that sub-goals of the overall goal are satisfied." An information flow model (Figure 4) "describes the information flows that exist in the activity of infusion administration...Communication between the doctor and the patient happens face-to-face, when the doctor is assessing a new patient or is examining a particular patient after that patient's condition deteriorates. Communication between the doctor and the current shift nurse happens face-to-face, and also via the EHR.	Qualitative	Observations, Interviews, Artifact Analysis
Interactions among physicians, techs, and nurses were critical to work in the trauma/ resuscitation bay.	Qualitative	Observations, Interviews
Outgoing nurses gathered data from EHRs, transferred this information to handover documents, and the presented it to incoming nurses at shift change. Outgoing nurses tended to lead the conversation during these handover meetings, while incoming nurses documented information in the EHR or their personal sets of handwritten notes. Handover activity was found to be composed of 2 main operations: 1) Handover preparation: "refers to all the activities carried out by outgoing nurses in preparation for the next operation." This phase focuses on, "collecting handover information and updating formal artefacts, such as care plans." 2) Handover meeting: "outgoing and incoming nurses gather for a face-to-face meeting. Outgoing nurses take the lead and verbally share their collected handover information."	Qualitative	Observations, Interviews, Artifact Analysis

Handoffs were described as "regular, formal" and were overseen by senior medical staff. Two key artifacts with teams interact at handoff: (1) handover sheet and (2) doctor's book.	Qualitative	Observations, Interviews, Artifact Analysis
Charge nurses are considered the owner's of the OR board. They interact with magnetic strips that represent cases on the board, as they are primarily responsible for writing the key case information down on the strips and properly placing them on the board. They are also responsible for rearranging personnel and rescheduling cases using the OR board. Indicator magnets serve as a "warning signal" to staff that a patient requires isolation precautions. OR technicians interact with and rely on "Patient Slips" that are pinned beneath the magnetic strips representative of OR cases to find information that they will need to locate that patient within the hospital.	Qualitative	Observations, Interviews, Photographing
Individuals and artifacts interacted on rounds as follows: Presenting resident interacts with charts to gather data before rounds; Presenting resident and nurse practitioner wheel around/ interact with mobile workstations that contain their paper notes and paper charts; A second, non-presenting resident wheels around a computer cart and retrives data from the EHR as needed; This may have involved acting as a "technology mediator" to pull up imaging and lab results for review; The cardiothoracic surgeon acted as an "auditor" to question treatment provided thus far and current assumptions about each patient's presentation; The ICU attending provided context/ justification/ rationale for care decisions made in response to the suregon's questions.	Qualitative	Artifact Analysis (accomplished through video recording), Observations

Study findings	Description of the physical layout
"The entire arrangement with folders represented the current clinical situation for the clinical team... Simply by *seeing it,* clinicians could estimate how many patients they were currently processing. It provided an *overview of the current situation* that enabled cinicians to naturally focus on the most important tasks..." "To track work-in-progress, clinicians placed patient records on a desk to form a shared public display that represented the current problem state for the healthcare team...patient records and other physical artifacts are used by clinicans in different ways to form cognitive tools that offload memory tasks and support joint-attention and collaboration."	N/A
The DiCOT approach allowed the authors to create a model of the OR that highlights the interdependence of technologies and humans. More detailed analysis revealed examples of work interruptions, information transformation, communication breakdowns, factors that triggered behavior, etc. The patient was noted to serve as an information hub that transforms data to graphical representation on monitors. The manual inputs required into infusion pumps was difficult and value to support cognition was minimal. Physical layout of the different infusion pumps could impede the anesthesiologists horizon of observation. Looking at monitors/pumps gives the anesthesiologist and resident a shared situational awareness and often triggered behaviors based on data. Anesthesiologists serve an information hubs integrating info from the patient, devices, surgeons and external sources. When 1 anesthetist steps away it reduces bandwidth and the safety feature of "double checking" (wherein 2 people supervise critical actions).	The spatial orientation of the OR is described in terms of the devices, team member positioning, and patient relative to one another. The OR had an anesthesia workspace, which included monitors and infusion devices, that was partially separated by the surgeons workspace by a surgical drape. There were external devices that were not directly within reach of any members of the team, but could be utilized if needed. The patient can be seen as being "in the middle" of the anesthetists and the surgeons.
A cognitive model characterizing the distribution of work and information flow was developed (Figure 2). Cognitive work was distributed within mini-teams that leveraged the expertise of different providers. Work was also distributed across mini-teams over time as shifts changed. Information was transmitted via artifacts and verbal handovers. External representations of information included 1) the whiteboard and 2) clinical notes. Handovers were informal and high volume (e.g., ~25 patients in 5 minutes), overwhelming the processing capacity of individual working memory. Shift changes were thus noted to be points in time where critical information was lost (as internal representations only stored in team members memories were not accessible once they left the ED). "Artifacts such as clinical notes play an important role in the preservation of information across time.."	Figure 3 shows a map of the shared workspace. 2 centally located whiteboards contain data for all patients in the PED in the shared central workspace, which is occupied by attendings and residents. The nursing and social work stations are adjacent to the central workspace. The central workspace contains an area for active patient files, computers to support clinician work, and a disposition whiteboard closest to the nurses' station. Entire area remote from medical ED.
"Information exchange patterns among clinicians fell into 3 main categories: (1) planned verbal discussions (e.g., rounds and handoffs), (2) unplanned verbal discussions of patient updates, and, (3) information exchanged via the EHR." The EHR was used by nurses and physicians for to: (1) direct an action, (2) share goals, (3) alert about abnormal or surprising information." After the presentation of a patient by the resident on AM interdisciplinary rounds, "collaborative decision-making occurred among nurses and physicians to generate the goals for the next 24 or more hours, and these goals were then documented by the attending physician in the EHR." Aditionally, "updates between disciplines were exchanged primarily through verbal communication during and between rounds."	N/A

Clinicians used an EHR system as well as multiple (personal) paper artifacts for documentation / to-do lists. Clinicians preferred verbal communication as a method of information exchange because they noted a perceived lack of effective and updated EHR. There was a shared perception that the EHR was a “shift behind”, leading to greater reliance on verbal information exchange, which is a valuable clinical communication activity, however, it is subject to information loss. Clinicans noted that certain aspects of ICU documentation inhibited workflow such as patient information contained in multiple disparate sections of the EHR, and information that was not updated to reflect current goals, while other elements of the system enhanced workflow, such as "documenting a plan...to help ensure that the plan will be carried out and its progress will be evaluated."	N/A
*Artifact analysis revealed highly structured, non-technical tools with significant content overlap across professions: The nurse Kardex was filled out upon patient admission and was added to by each shift. It stayed at the bedside... It was written in pencil to facilitate updating of the synopsis. The Kardex would be reviewed if the oncoming clinician was unfamiliar with the patient. The nurse personal handoff sheet contained more detailed shift-to-shift information (e.g., meds and doses, inputs and outputs, labs/critical values and actions, test results, tasks and to-dos, etc.) This paper-based form was filled in at the beginning of each shift and maintained throughout the day/night (with a new one generated each shift). The resident/PAs maintained a computer-based handoff tool (not linked to the EHR). This document was collaboratively updated each shift. The oncoming resident would print it off and annotate it during handover, and they would update the computer document prior to the end of their shift. *Of the 827 handoff elements coded from the artifacts, 92% were interdisciplinary and many elements were specific to the specialized ICU.	Locations of handoffs were described: Nurse-nurse handoffs happened within sight of the patient's room and involved visual reference to the patient/therapies; Resident-PA handoffs occurred at a central nurse station and rarely involved visual reference to the patient.
The authors "identified 137 unique surgical cognitive processes, including 33 decision points, 23 critical communications, 43 pitfalls, and 38 strategies" across 14 steps in the procedure (Table 2). Perceived cognitive workload was measured across each step, and 3 tasks - separate from bypass, anastomoses, and cannulation - were identified as imposing the highest demand on the surgical team (see Figure 2). The authors "results show that self-reported cognitive workload is not uniformly distributed across distinct surgical steps and OR team roles." An interactive dashboard that provides integrated visualization of team cognitive processes was created to "enable surgeons and educators to interact with the data and explore expert cognitive processes while navigating through the surgical workflow." (https://public.tableau.com/profile/cognitus#!/vizhome/CognitiveTaskAnalysis-CABG/CTA)	N/A
1) "Glucometer performance is coupled with different individuals/ groups, adjacent equipment, training, policy decisions and different tasks." 2) Artifacts model: "The docking station...allows the glucometer to upload and download data to a central database. This plays a critical role in information movement, making locally recorded information available hospital wide." 3) Social model: Healthcare assistants often tell patients their readings, contributing to the situational awareness of the patient. 4) Information flow model: The task of reading a blood glucose "orchestrates different mediating artifacts to identify specific staff and patients, allow access to use the device, and how it transforms blood glucose levels from a droplet of blood into a numerical value." 5) The physical model higlightedconstraints placed on device use, difficulty with notifying a nurse of abnormal readings, and its ability to convey information to multiple hospital locations simultaneously via a centralized database.	An oncology ward with "24 beds: 16 are in 4-bed bays and the remaining 8 are single side rooms"

"Infusion practice is part of a complex sociotechnical system that involves different tools and technologies, distributed over different people and physical space, over different periods and patterns of time." "At the micro level, nurses experienced repeated patterns of the same drugs, doses, infusion rates and volumes for patients with certain conditions." Common infusion administration relied on meaningful schemas. "Structural elements of the sociotechnical system provide it with shape, constraints, expectations and plans." "The agency theme captures people's resourcefulness, inventiveness and volition" ("adaptations and workarounds"). "The performance variability theme captures positive and negative deviations from norms established at the individual, ward, hospital or national level" ("incidents, near misses and discrepancies").	A diagram of the hematology ward layout was provided, and the spatial relations among patient rooms, office areas, staff areas, waiting areas, active reception areas, and the ward managers office were illustrated and described.
Doctors gave goals to nurses (e.g. get blood pressure up to X using these drugs) so that nurses could act flexibly and autonomously. Beds at the extremities of the ward are some distance from the central hub area, which makes access to live information discussed in the central hub more important. Social structures model used to highlight interactions between different staff members. Closed-loop EPMA documentation system is supported by an onsite technician who troubleshoots technical issues. Offsite support for more challenging issues was provided by a remote technical team. Nursing safety network managed safety reporting and learning. Senior nurses would write reports on incidents and near misses, with learning filtered to nurses and other staff on the ICU.	*ICU layout* : 2 wings with a central doctors' hub in the middle. Beds at the ends of the ward are some distance from the central hub. *Patient bay (room layout)*: the trolley, table and EPMA table are used for infusion prep. Space around the bed was limited, especially where extra pumps go beyond a single docking station. *Central doctors' hub* had 4 desktop computers where doctors sit and access patient records and the EPMA system. The overview screen provides a summary of the ward's and patients' statuses, and it can be used as a shared screen to discuss graphs and scans together.
In the first step of the ED process [patient triage –> room], information flow was mediated by a technological artifact, as the triagist and the physician were not in sight of each other from their workplaces. Physicians can see time of patient arrival, emergency codes plus short description of symptoms, but must enter a new screen to view a detailed triagist report. Some physicians only looked at the default screen. In addition to "official information" noted by triagists via the formal system, they also sent "non-official" info to physicians. Two main functions were performed by the nurses. They could act as memory keepers and process organizers. "In their memorykeeper function, the nurses kept in mind which laboratory reports had arrived and which were still to come, the set of open cases, the patients waiting for re-evaluation and those who were to be discharged." By taking on the function of process organizer, the nurses appeared to provide an important support to the physician decision-making process, specifically in searching for and highlighting the information that enabled the final decision to admit or discharge the patient" More informal interactions between physicians, nurses, and triagists were more likely to occur if the quality of the relationship/rapport among team members was better.	N/A
Situations that relied on dependent memory were classified in 4 categories: 1) Episodic tasks 2) Habitual tasks 3) Interrupted tasks 4) Interleaving tasks No atypical tasks were identified	N/A

"570 (20.8 per hour) distractions were coded. These include 239 (41.9%, 8.7/hour) acknowledgments, 150 (26.3%, 5.5/hour) multitasking episodes, and 181 (31.8%, 6.6/hour) interruptions." "Longer interruptions result in longer resumption times...Physical context changes due to interruptions resulted in longer resumption times." "General strategies can remind nurses about forgotten interrupted tasks. They include scanning the top of the bed area while washing hands, looking at places where artifacts are generally placed, and accessing the clinical information system..."	Tertiary care ICU. Each bay was equipped with a computer with a clinical information system.
"Four separate types of error were discovered. All four cases were determined to have originated during the registration process" Of note, two of these were cases of duplicate MRNs, which limited the physicians ability to access PMH, one was a case of improperly updated demographic info, and one was misidenification of a patient because he/she was given an incorrect wristband. The registration staff is often interrupted. This results in a considerable amount of multitasking, and high cognitive load. To process patients in the shortest time possible, staff members adopt a number of workarounds. "Times of work overload and high patient volume increased error rates" "Each error represents a breakdown in the overall distributed cognitive system that defines the registration desk and the ED." "Although the adoption of technology may benefit the ED, the results of this study suggest that the existing generic electronic tools alone may be ill-suited for this environment. These tools must be tailored to support adaptive processes like multitasking and handoffs that occur in a time-constrained environment."	The layout of the registration area was documented in a figure highlighing the interplay between registration clerk, EMS, patient, and technologies that support patient registration (computer, pagers, phone, etc.)
Providers in the unit have organized themselves with respect to the medication administration system, with respect to each other and their task work. Consequently, deviation from standard practices involving the medication administration system are more easily detected and create opportunities for learning. In other words there is "shared awareness" about mistakes and a comprehensive and efficient plan for reconciling discovered discrepancies. Robustness in performance of this activity system relies upon information playing many different roles within the system. Redundant representations encode similar information in different forms utilizing multiple kinds of media. This makes the information available to distinct but interrelated interpretive processes. Such redundancy ensures robustness and correctness in the functions performed by the system. Actors in distinct roles each control and manipulate their own representations. This facilitates engagement of task work and thereby focuses attention upon issues that ensure proper system functioning.	N/A
As uncertainty increases due to progression from expected to unexpected variability, initial plans operationalized through preparatory configuration become less relevant. Emergent coordination of actions through replanning becomes imperative. Preparatory planning's ability to ensure an exact outcome as it is limited by: (1) planning for the unexpected, (2) flexibility that allows for spontaneous re-planning, (3) novelty introduced by new staff/technology/policies. Annotated cheat sheets "enable OR staff to translate general inventory lists into arrays of tools organized for use across time in a specific case with a specific surgical team. The layout of tools, in turn, becomes a rich representation of practice that simplifies the cognitive demands of tool provision during surgery. Resources distributed across the activity system enable replanning while dynamically balancing the demands that replanning places on other ongoing and important activities of the system. Redundancy in processors/processes, plans and resources instill resistance into the distributed cognitive system in the OR.	Figure 1 shows the layout of the open-heart surgical room during setup or “preparatory configuration” for surgery. Once surgery starts, the room will be rearranged with the “back tables” and heart-lung machine arranged closer to the patient, effectively “boxing in” a sterile field that encompasses the patient, and providing the area where surgeon, physician assistant (PA), and techs work.

6 patterns of information exhange were identified, each focused on a ‘‘task’’: direction, goal-sharing, status, alert, explanation, and problem-solving. "Directions are common and sometimes very formalized forms of communication." "Formality increases with engagement in high-risk or hard to reverse actions, especially actions that are not fully accessible to multiple agents in the activity system." Goal sharing "sets up the expectation of reaching a future state, as opposed to focusing on the specific pathway or sequence of actions required to reach that target." Status exchanges are "often initiated by a request for information" but can also be "volunteered." "Alerts are generated by events that create a perceived deviation from the expected or desired system state" and also "project a need for possible corrective action." "Explanations are offered to reduce uncertainty about the current state and the pathway that lead to it." "Problem solving typically involves a series of turns that include alerts, explanations, directions, status reports, and goal sharing. Actors state facts that highlight uncertainty about the system state...in an effort to explain the facts, create coherent understanding, and reduce uncertainty.	Figure 1, shows the layout of "the heart room" in which "the surgeon stands directly adjacent to the patient, typically with his hands in the patient’s chest and his attention focused on manual (and tool-mediated) manipulations of the heart. The perfusionist occupies the space behind the surgeon, and the bypass machine sits between the two. The surgeon’s back is to the perfusionist, and the perfusionist and bypass machine both reside outside of the sterile field."
"Nurses expressed complete certainty, '5', in their acuity assessments in 72% of cases, and never reported a certainty below '3'." There was a significant positive correlation between number of medications and nurse-estimated quantity, indicating that nurses have a "well-developed mental model of medication quantities." Nurses reliably identied the most acute patients in the unit and this wa a reliable predictor of mortality risk. "The number of variables that nurses were watching was not a signicant predictor of patient acuity." Vitals were the most watched variable. "Because of the physical configuration of the unit, vitals, ventilator presence and the number of drips were visually available. This explains the assertion that nurses were most aware of the status of nearby patients, i.e., they were aware of the information available within their horizon of observation.	Figure 4 shows the spatial layout of the ICU, and specifically maps the location of patient monitors/rooms. These are located in a semi-circle at the perimeter of the unit, with centrally located desks where monitors record and display vitals for several patients.
"By framing our observation in the context of DCog and using DiCoT as an exploration tool, we found that poor information flow and limited scaffolding expose hospital staff to contagions." "When a patient is “on isolation,” signs act as a trigger factor, cuing staff to don the appropriate gear. Signs are fixed to the doorway for visibility." "Patient isolation status and type can be inferred from external Scaffolding." Things like the patient wearing a mask or notes in the EHR about infectious agents can trigger staff to hang isolation signs. Absence of key scaffolding clues/external representations can lead to delays/errors in infectious agent protocols.	N/A
"The EHR has the advantage of supporting dialogue between colleagues who are not co-located, provided they all have access to the same EHR. However, "personal notes on paper...remain central to the creation of a clinical overview...personal markings in the record function as a support for the identification of critical information." "Among the changes" associated with the transition from paper records to the EHR "that were found to be beneficial were a more promptly updated and well-ordered patient record; information that stayed in place once entered; and greater accessibility to the record and to any information in place once entered." Yet, "the paper-based patient record has features that support the creation of clinical overview... the possibility of using a flexible and individual layout with numerous typographical options was appreciated in the overview process. Several of these typographical features which facilitated the physicians’ overview of the records were lost in the transition to the EHR."	N/A

"Paper charts were used as the information source that contained notes by residents at patient admission, attending notes, orders, tests, and other administrative material. While paper records were information-rich and mostly current, they provided the physician only a snapshot view of a patient...updates to the paper records were manual and slow." "Electronic charts contained updated information about test results, information from bed-side monitors and vitals." There were no significant differences in the overall time spent on paper when compared to electronic charts but more time was spent on evaluating the physician notes on the paper record than on the electronic record and significantly more time was spent on electronic records for retrieving information regarding orders, medications and laboratory results. "Overall, more information was retrieved from paper records, but the information retrieved from the EHR was significantly more unique and consequently, led to higher information gain"	N/A
6 items made the maternity ward safe: 1) *Collective competence* : "training days supported the development of social relationships and a sense of interdependency, providing an opportunity for staff to learn together and to develop their understanding of each other's roles and responsibilities;" 2) *Insistence on technical proficiency* : individuals were required to be able to perform their clinical tasks to a very high standard of proficiency, with visible effects on staff confidence, readiness, and competence when responding to crises; 3) *Monitoring, coordination, and DCog* : "deliberate effort went into anticipating and mitigating stresses, and facilitating shared awareness; *4) Clearly articulated and reinforced standards of practice:* handovers, briefings, and safety checks were taken seriously and conformity to professional norms and graduated sanctions brought behaviour in line; 5) *Monitoring multiple safety sources* : an automated dashboard monitored performance by identifying any concerning trends or patterns;" 6) *Highly intentional approach to QI/PS:* the unit attended to operational fitness – ensuring that the workflow and systems were optimised to the tasks that teams needed to accomplish.	N/A
5 key themes emerged: 1) *Hierarchial power and authority* : "data showed that staff in higher positions seemed to have more power and influence in the discharge process, including discharge decision-making and discharge practices." 2) *Competing priorities* : "ICU physicians and nurses often faced competing demands for ICU beds, which explained why ICU staff were proactive and aimed to discharge patients as soon as possible." 3) *Ineffective communication:* "Information loss in ICU to ward nursing handover was obvious when the information given by the ICU nurses and the information received by the ward nurses were compared." 4) *Failing to enact the organisational processes & working collaboratively to optimise the discharge process:* "Hospital patient data and bed management computer programs were not used effectively." 5) *Working collaboratively to optimise discharge* : "Some staff members worked beyond team and department boundaries to optimise discharge and ensure patient safety."	N/A
Physicians were interrupted on average 11.9 times per hour and interrupted others 8.8 times per hour. Nurses were interrupted 8.6 times per hour and interrupted others 5.1 times per hour. Interruptions were attributed to seven sources: (1) clinicians on the same team, (2) clinicians in the same unit, but not on the same team, (3) clinicians external to the unit (i.e., consultants), (4) patients and family members; (5) non-clinical sources (e.g., hospital utility services); (6) phone calls or pagers; (7) devise alarms. Types of interruptions: Information seeking and sharing (n = 259, 46.3%, average resumption lag 56s); directives and requests (n = 70, 12%, average resumption lag 1min 3s); shared decision-making (n = 49, 8.8%, 1min, 38s); direct patient care (n = 36, 6.4%, average resumption lag 1min 38s); social (n = 71, 12.7%, 1min 7s); device alarms (n = 28, 5%, 47s); non-clinical (n=10, 1.8%, 41s). "Of all interruptions, 29.5% were classified as being better served with computer-mediated communication."	N/A

5 key themes emerged: 1) Preparation: preparation of the PCCAT disclosed that the process of seeking, selecting, and formatting the data, enabling the nurse to “develop a snapshot” of the patient’s clinical problems, current condition, and care needs. 2) Handwriting: the nurses expressed that the act of recording data on the PCCAT reinforced awareness that data was available. Personal notations enabled the nurse to record new results, create alerts and reminders, and make notations for later entry in the medical record. 3) Information Visualization: selecting and writing data on the PCCAT enabled the nurse to create visual cues or reminders that augmented internal knowledge, and supported later formal documentation. 4) Recall/Visual Cues: each nurse created PCCATs that demonstrated consistent and personally meaningful spatial, proximity, chronology, and other visual data display patterns. 5) Organization & Prioritization: the PCCAT served as a key instrument to understand the needs of each patient in the nurse’s assignment, while also serving as a visual representation of the work that needed to be completed for all the patients assigned to the nurse.	N/A
"The activity of purposeful improvement is distributed socially (e.g. patient families, health care team) and materially (e.g. procedure, patient position, instruments, OR equipment) as well as over time (i.e. before, during and after procedures)." "The importance of the physical and social construction of the procedure was observed in the thoughtful enactment of the preoperative instructions." "During procedures, the surgeon directed and continually reinforced the purposeful improvement, for example adapting existing routines like the preoperative huddle in order to support the ongoing introduction of improvements." "He used this reflection to further design his clinical context to support the ongoing use of previously enacted improvements, including the development of an audiovisual library"	N/A
Four artifacts support DCog in the OR. Three of them are hard copy printouts (availabilities sheet, master schedule, OR graph) and the fourth is a dry marker board (OR board) with moveable magnetic plaques." Artifacts that best support DCog in the OR have the following characteristics: 1) Reliable / Available when needed; 2) Informative; 3) Efficient; 4) Clear & Unambiguous; 5) Accurate; 6) Malleable (able to be manipulated by those who use them). The OR Board is arguably the most important artifact as it holds the plan and resource status across time. The AC uses its content as a means to develop a consensus and embody the future. By holding the plan and status information through the day, the board distributes cognition among the staff. The Master Schedule and the manipulations to it are critical for maintaining and distributing resources across time within the system: "The preliminary and master copy versions of the Master Schedule are efforts that the institution makes to capture and channel the flow of demand so that resources can be allocated to meet it."	N/A
Efficient handoff communication attends to Grice’s maxims: 1) Quantity: Make your contribution as informative as is required (for the current purposes). 2) Quality: Say what you believe to be true. Do not say that for which you lack evidence. 3) Relation: Be relevant. Use verbal and physical gestures to convey information efficiently. 4) Manner: Avoid obscurity of expression. Avoid ambiguity. Be brief. Be orderly. "Fellows employed highly encoded language, cues, and terms that facilitated their interchanges by using stylized expressions and protocols rather than playing language."	N/A
The authors "identified 21 key challenges and barriers to safe and effective clinical care on the BICU (Table 2). A descriptive model of BICU cognitive work was developed. Barriers to cognitive work were identified, as well as requirements and key elements for IT design.	N/A

5 documents were used during nursing handoffs: a Kardex, Critical Care Flowsheet, Charge Report, Hand notes, Patient chart (paper). "All resources were referred to 636 times during the 40 handoffs...the amount of times resources were referred to during shift reports ranged from zero to 60 times, with an average resource use of 16 (SD-13.9) times per handoff." The most commonly used documents (in descending order) were: critical care flowsheet, kardex, patient chart, hand notes, charge report. Duration of shift reports ranged from 3:21 to 23:02 minutes, with an average duration of 13:10 minutes...durations of shift reports were related to the amount of resources used with a [statistically significant] positive linear model.	N/A
Medication administration was a 3 phase process consisting of a prescription, dispensing, and administration phase. Nurses play a role in all of these stages, while physicians are most important in the prescription phase, and pharmacists are most important in the dispensing phase. This system relies on DCog to coordinate efforts across individuals (nurses, physicians, pharamacists) and time (nurses from different shifts must communicate/coordinate at shift change). This study "allowed the identification of a number of organizational factors": cooperation/ communication between physicians and nurses (rounds, briefings, opportunistic); speed of the patients' clinical process; frequency of medication orders; characteristics of the drugs used.	N/A
The overall function of the ICU is to receive patients from other wards who are in a critical state and are in need of intensive monitoring, or who need post-anaesthetic care, and to take care of them until their condition is stable enough for them to be returned to normal wards. This is captured by the high-level input-output model (Figure 1). Results are ultimately reported in the form of DiCOT-specific models: *System activity model*; *Information Flow model*; *Physical layout model; Artefact model.* "The results of the study portray the ICU as a socio-technical system, in which healthcare practitioners rely on sophisticated technology to achieve the goal of sustaining and treating critical patients"	A well diagrammed layout of the ICU at the bay, bedside, and infusion station levels is provided. Figures 5&6 show a physical layout model that analyzes how the physical environment supports communication among actors and access to artefacts, and how spatial arrangements simplify choice, perception, or internal computation.
A teamwork model for trauma resucitation was developed using dual processing and DCog theories, in which the trauma team members occupied roles within the dual processing model of the system (Fig. 3) but engaged in directional interactions with other actors, artifacts, and information in the system. From there, using the heuristic "IF symptoms-observed THEN diagnosis DO apply-appropriate-treatment," the authors developed a model of rule based team behaviors in which the rescusitation team leader diagnoses the problem based on evidence gathering done by other actors within the DCog system. He/she then orders/monitors a plan that is executed by his/her team (Figure 4). This is a cyclic/iterative process. The working memory of the DCog system is the combination of externally available situational information and medical reference information, as well as internal information carried by each individual team member. "The accrued information is stored in a trauma team's collective (or transactive) memory, rather than being externalized for reliable storage and easy access," which creates susceptibility to information loss from the system.	N/A
3 key analytic themes were identified using DCog: 1) Use of EHR as a cognitive handover artefact: outgoing nurses transferred patient information back and forth between their notes/ handoff documents and the EHR in preparation for the handoff meeting. 2) EHR properties that affect its use as a cognitive handover artifact. The following properties contributed to or impeded the EHR to serve as a handover artefact: Information documentation, information provision, accuracy and preventing the loss of documented information. 3) The handover sheet as an essential cogntive artifact: ""Handover sheets provided nurses with a standard and structured information-set"	N/A

"Usability problems with the handover sheet included the difficulty of transferring handwritten symbols to the electronic document, the laboriousness of compiling the update from other information resources on the ward, and the loss of information that occurred when completed jobs were deleted from the electronic document." For the doctors' book, the problems included the lack of space...resulting in insufficient space for each patient, messy and illegible hand writing, the fact that the book was too cumbersome to carry around, and it took too long to write." Updating the handoff documents triggered a "checking of the state of the ward," that forced teams to reflect on the clinical status and diagnostic/therapuetic intervetions needed for each patient.This process had a net "positive effect on the accuracy of other information resources in the setting, including the knowledge of the staff."	The handover sheet was updated on the computer at the nursing station on the ward. This was a central location where the most accurate information about the ward was available from information resources including the ward whiteboard, medical notes, patient administration system and other staff. In contrast, because the doctors' book was portable, it was updated not just at the nursing station but also in a variety of other locations.
The OR Board provides an overall, external representation of the OR unit, as it visually displays/track cases and staff throughout the physical environment. The OR board serves as a gathering point and communication hub for providers and staff at all levels. The OR board makes coordination among team members and the coordination of specific tasks less burdensome (particularly for charge nurses).	Physical layout is described in Figure 1: "The OR is separated from the resuscitation unit. When surgery is over, the patient is transferred to the post-anaesthesia care unit, nearby on the same floor." The central OR Board is located at the intersection of the trauma resucitation unit and OR unit. The layout of the OR Board was described in Figures 2-8: The board is partitioned in 3 distinct areas - the leftmost contains scheduled cases, the central area contains "add on" cases, and the rightmost houses magnetic name tags for OR staff; Cases are represented by magnetic strips with pertinent info written on them.
Many individuals who participated in rounds, "brought with them paper documents" that they use to quickly access patient data and take notes. These were noted to be critical external representations that contribued to DCog in the healthcare space. "Shared displays, such as X-rays and trend plots of patient variables, were exploited to support joint sense-making" of lab and imaging results within the context of the patient presentation. The rounding team gradually built up a shared understanding of care status and plans by progressing, "from [presentation of] basic facts, to analysis of underlying issues of the patient, to treatment plans and options." This scaffolding process allows teams to build common ground that informs management decisions.	N/A

Elements of DCog systems presented	Possible sources of error identified	Potential interventions to address error
Information flow, coordination among team members, external representations	N/A	N/A
Spatial layout, information flow, coordination among team members, computation/ combination, horizon of observation	(1) Masks decrease nonverbal communication; (2) Surgeons & anesthetists have different horizons of observation & shared situational awareness is decreased; (3) External persons can enter the OR and interrupt; (4) Artifacts like phones distract; (5) Suboptimal communication between infusion pumps and monitors; (6) Overlapping infusion pumps obscures the anesthetists' horizon of observation; (7) Only one member of the anesthesia team is typically present at any given time which reduces the team's bandwith and eliminates a buffer against error; (8) Omission of information at handoff limits the ability of the oncoming team to "double check" the situation.	N/A
Spatial layout, information flow, coordination among team members, communication between patients & providers, internal/ external representations	Several latent safety threats were noted: Handovers and loss of information due to high volume of patients with inadequate details transferred; whiteboard and clinical note handwriting & lack of detail to support clinical decision making; communication failures between the mini-team and other units of the hospital; lack of check and balance system for medication orders (e.g., led to wrong dose administered) spatial distribution (remote from the medical ED) created challenges related to medical clearance, especially when medical issues were later discovered in the psychiatric ED.	The authors noted that a more structured handover process was implemented that leveraged an external representation (a handover form). Solutions to the other safety threats were not discussed. The authors noted that future work would focus on "the development of tech interventions that shift the distribution of cognitive work so as to support latent flaws"
Information flow, coordination among team members, internal/ external representations	Sources of error were described as "barriers" to interdisciplinary exchange in the ICU. These included: "A system of ad hoc updates;" "Implied and outdated goals;" "inefficient information retrieval;" "inadequate structures to represent information and communication in the EHR;" *Due to insufficient EHR systems, the ICU system is over-reliant on verbal communication. This can result in interuptions, errors of omission and information loss. Information loss may be greater on night shifts as the formal structures for decision making (e.g., rounds) occur exclusively during the day.	The authors developed a model of EHR interdisciplinary information exhange that incorporated 6 elements: (1) collaborative decision-making (2) explicit common goals (3) double checks (4) interventions (5) sssessments (6) evaluation of goals. Producing an improved EHR model required: "EHR information tools that synthesize and summarize updates and events related to explicit goal generation, implementation, assessment, and evaluation;" "Communication tools that allow for clinicians to contextualize patient data and exchange domain specific knowledge for collaborative decision-making and patient safety double checks 24h/ day."

Information flow, coordination among team members, internal/ external representations	Failure to explicitly state goals during AM rounds can lead to information being placed in the ordering system that is never acted upon (it is "forgotten, missed, or not prioitized"). "The current structure of the EHR and content of the documentation tools in the ICU may not be sufficient to capture the information exchange of common goals that occurs during and in between ICU interdisciplinary morning rounds."	The design of EHRs and CPOE systems that facilitate capture of up-to-date goals and rationales related to patient care may improve safety. For example, when physicians enter a new order, requiring input of a rationale or explicit goal may help minimize the need for verbal exchanges, as it can provide a double check. The development of EHR tools to support efficient information exchange of routine data at handovers could also increase the efficiency and safety of information exchang
Coordination among team members, internal/external representations	"The artifact analysis highlighted the limitations of a system that is not integrated with the EHR, including a high degree of transcription and siloed information, that have been linked to ineffective communication and potential sources of error in patient care." There were safety features of the paper artifacts (e.g., easy summarization and capture of temporal nuances; circling critical values and notating medications given in response) that could be lost in fragmented displays of poorly designed EHRs.	The authors highlighted the need for structured narrative handoff tools, with designs that blend coded data elements for selection by clinicians with free-text data enty.
Coordination among team members	The authors did not mention specific sources of error beyond those that could potentially arise in a CABG procedure. Rather, they focused more on discussing how "critical communiction points" and "strategies" that were identified were crucial to avoiding "pitfalls" in the OR.	The authors noted that workflow segmentation may inform design of intraoperative cognitive guidance systems, such as smart checklists and decision support systems to enhance safety. "By understanding the cognitive demands imposed by specific tasks on specific team members, technology enabled guidance systems may offer clinical support tailored to specific task demands and OR roles."
Information flow, coordination among team members, communication between patients and providers	1) "A healthcare assistant was observed to use three testing strips for one reading. On enquiry it was revealed that he should have waited for the device to display a small icon before applying blood to the strip." 2) The device cannot be used for individuals without an ID, which could be problematic in a situation where a visitor collapses and needs a STAT fingerstick glucose. 3) On a busy oncology ward with many rooms, it can be difficult for a healthcare assistant to quickly notify a nurse of an abnormal reading, which can delay information flow and possibly lead to errors of ommision	1) The small icon on the display contributed to the error with the glucometer that required repeat testing with multiple strips. This could be rectified by making the 'ready to use' icon more prominent. 2) To get around the issue of scanning IDs, those monitoring device inputs (biochemist / diabetes nurse specialist) noted that specific codes could be entered to utilize the device in an emergency. 3) Healthcare assistants could be supported if they cannot find the patient’s nurse to warn them of a high or low reading. 4) Better staff training about how data is uploaded/downloaded, and the final location of the uploaded data could help staff better understand the device's use, which could help with real-time trouble shooting

Spatial layout, emergence, coordination among team members, communication between patients and providers, information flow	"The physical structure of the ward appeared to conflict with the interactive configuration of the infusion pumps. The pumps alarmed 10 minutes before the end of an infusion, which meant patients had to summon a nurse to silence the alarm, only for the nurse to have to come back ten minutes later. Downstream consequences included frustration for the nurse and patient, wasted time,... patients directly interacting with their pumps against hospital rules." "It was suggested by a nurse that this learned patient behaviour could have contributed to cases of pumps running out of battery and stopping early."	Eliminate the infusion pump alarm prior to completion of the infusion.
Spatial layout, information flow, coordination among team members, internal/ external representations	Oudated drug library within EPMA; Manual pump mapping for patients with more than 8 pumps; Electrical plug malfunctions/ computer system glitches leading to administration and tracking errors; Lack of drug allergy detection mechanism built into the system; User error with pump programming/mapping	N/A
Information flow, coordination among team members	The physicians "different ways of interacting" with triagists "via the computer revealed that there was no shared agreement among the physicians about the criteria involved in prioritizing patients or how to use the clinical information obtained during triage." "Not using both screens resulted in a loss of information and flattened relevant clinical information, with the potential to negatively affect patient prioritization." "If physicians switched from the default screen to the clinical parameters screen, they might temporarily lose track of new arrivals, including potential red codes." "Informal actions" of the triagist (i.e. going to speak directly to the physician) "could affect patient safety: leaving the triage workstation unattended...potentially means a lack of control at reception for three or four minutes."	N/A
Information flow	N/A	N/A

Internal/ external representations	N/A	N/A
Communication between patients & providers, information flow	"Third party data collection creates a susceptibility to breakdown of communication and potential errors." "Not all patients possess or are willing to share the required set of information necessary for registration. In such cases, the patient is admitted with little or no identifying information. This is one of the major factors in introduction of errors into the process." "Shortcuts and workarounds, combined with the inherent difficulty in the functionality of the computer system, results in the occurrence of errors and potentially adverse events." In the case of the incorrect wristband: "A failsafe exists to prevent this type of error. Any personnel applying a wristband is required to identify the patient by two means. In this scenario, this procedure was not followed."	"It is possible that improvements in the computer system as well as better training of the staff to use the system can result in significant reduction of such errors"
Information flow, coordination among team members, computation/ combination, internal/ external representations	1) An example case provided highlights an error in medication administration stemming from duplicate orders placed in the medication administration system 2) "Illegible handwriting, non-standard use of language, and the overhead associated with paperwork activities are undesirable barriers for safe and efficient care processes"	N/A
Spatial layout, information flow, coordination among team members, internal/ external representations	Certain "tools become difficult or impossible to identify when they are provided for use" without proper labeling/packaging	The authors suggest that error may need to be redefined so we can better approach ways to identify errors and intervene. They suggest adopting a theoretical framework that can accommodate both individual and system-level phenomena. DCog is a systems approach that focuses on cognition and situated interaction to explain behavior at both the individual actor and system levels. As such, we believe that DCog provides a productive framework for advancing understanding of how error occurs and how it can be reduced in complex work practices.

Spatial layout, information flow, coordination among team members, internal/ external representations	N/A	N/A
Spatial layout, horizon of observation	The "volume of irrelevant alarms desensitizes nurses, leading to inappropriate behavior during real emergencies" "Too much of the cognitive burden of determining whether a physiological state requires action falls on nurses. This burden exceeds their available cognitive resources, resulting in alarm fatigue."	"Designers of the next generation of monitors should reduce alarm fatigue while avoiding overtrust by prioritizing alarms in a way that nurses understand." "Perhaps counterintuitively...the system should be inaccurate enough to avoid overtrust, so that nurses monitor the raw data."
Information flow, coordination among team members, horizon of observation, internal/ external representations	In the case of contact isolation, masks are absent. Since these serve as the primary indicator of isolation status for staff, the recognition of this (although available in the EHR) may be delayed. Consequently, staff can be exposed to pathogens, especially in emergency situations, if they are overreliant on this artifact for action signaling. In some cases, isolation status fails to be documented in the EHR entirely. Lack of gowns for contact isolation patients during transport further propagates risk of contagion spread due to absence of characteristic cues for staff. Multitasking can contribute to poor communication, interruptions, and failure to employ precautions in a timely manner.	We propose deploying a digital sign next to each patient room, within the Horizon of Observation, to replace paper isolation signs. "The ED records isolation in the EHR, and the device can display it automatically when a patient arrives in the ICU." "If a contagion is discovered during the patient's stay, staff may hang the sign and simultaneously record it in the EHR." "When the patient is moved to a floor, their isolation status follows them, because it has been recorded via the device." "Masks could be color-coded by isolation status, to reduce the likelihood of selecting the wrong mask to use during transport." "Contact-isolated patients could wear gowns, or nurses could wear gloves, during transport."
Information flow	"Numerous instances of failure to update the material placed in the paper-based record" were noted. Information overload: "If a patient had been treated in many different departments, there would be much information in the record which would make it difficult to find the relevant pieces of information." A "lack of typographic options in the EHR constituted a considerable obstacle to the creation of clinical overview. The problem mainly concerned the physicians' progress notes. In the paper-based records, the secretaries would highlight text and place the text in a number of standard locations by making insertions, right positioning and bolding text, etc."	N/A

Information flow, coordination among team members, internal/ external representations	N/A	N/A
Information flow, coordination among team members	The following factors contributed to the breakdown of safety: *(1) financial constraints, (2) severe staff shortages, (3) increasingly complex situations, and (4) deteriorating physical in frastructure.* These factors "affected proactive risk management, hindering the team's alertness to small signs of deterioration, and caused exhaustion and stress as shortages meant staff were unable to take breaks during 13-h shifts. The increasingly challenging environment impacted on the whole system, creating frustration, sparking tensions between management and frontline clinicians, affecting collegial and supportive behaviours, creating psychological distress, and reducing organisational citizenship behaviours.	N/A
Information flow, coordination among team members	Communication was ineffective in the discharge process. Information loss in ICU to ward nursing handover was obvious. Lack of documentation for verbal handovers was one of the reasons for the information loss... There was no process for staff from different departments to share their decision-making processes and ask questions. There was ineffective communication between nursing and medical teams within departments. Because ward staff often did not update the computer system with patient discharge information and failed to comply with a trial of bed management software, the hospital bed managers had to talk to clinical nursing leaders to determine where empty beds existed. This manual management process was inefficient and nontransparent and, in some cases, contributed to discharge delays and communication breakdowns.	N/A
Information flow, coordination among team members, communication between patients & providers	"It appeared that verbal communication was the main channel for disseminating assessments and care plans between clinicians external to the unit, for example consultants and pharmacists, and members of patient care teams who were co-located in PICU. These were often passed among team members through the word of mouth until the official note was deposited, thus presenting numerous opportunities for information loss and distortion."	"Better information displays that include up-to-date patient information obtained, for example, through integration of EHR systems with patient monitoring equipment." "Other researchers argued for the need to improve automated capture of patient information that could improve information flow and reduce the need for manual documentation"

Internal/ external representations	"In the absence of optimal data content and configuration, the nurse may fail to effectively perceive information that is important to patient care decisions, and possibly increase risks to safe patient care."	N/A
Information flow, coordination among team members	"Interestingly, keeping up with laparoscopic techniques and instrumentation occasionally had adverse effects on other aspects of the procedure, requiring an ongoing commitment to addressing emerging problems in a systematic way."	N/A
Information flow, coordination among team members, internal/ external representations	The paper based master schedule created by OR coordinators generally embodied the key artifact characteristics to a greater extent than their electronic/ computer-based counterparts. Thus, the electronic/ computer-based artifacts were prone to error. Surgeons often sequester resources or try to overestimate the time required for a procedure to gain an individual advantage over others in the system. The AC/NC must work to actively combat this to preserve the function of the system. Additionally, patient flow can be threatened if procedures take longer than expected or if unforeseen procedures need to be performed.	Computer-based artifacts could be improved as follows: prompting (add a survey function that alerts OR coordinators to gaps/ inconsistencies in the DCog network); speculation (add a feature that provides an array of possible future actions to help coordinators make decisions about how to direct future work); consequences (add a feature that highlights the downstream effects of particular decisions (effects on biling or cost); value-based decisions (provide electronic templates that coordinators can choose from to make planning and decision making easier and more value-based.)
Coordination among team members	N/A	N/A
Information flow, coordination among team members, internal/ external representations	N/A	N/A

Information flow, coordination among team members, internal/ external representations	N/A	N/A
Information flow, coordination among team members	N/A	N/A
Spatial layout, information flow, coordination among team members, communication between patients & providers, horizon of observation	N/A	N/A
Information flow, coordination among team members, internal/ external representations	4 types of errors were identified (Table I). "In the DCog system, errors in performance are mainly due to failures of communication or working memory: 1) Communication errors occur due to ambient noise, mutual interference, misunderstanding and information loss; 2) Vigilance errors occur "when a team member accepts erroneous input uncritically" and uses it in his or her task; 3) Interpretation errors result from a compounding of communication errors, team leaders ignoring weak cues in anticipation of stronger ones or failure to integrate multiple, weak cues effectively; 4) Management errors occur when the team leader loses track of progress on the treatment plan.	We identified three potential approaches for computerized support in safety-critical settings characterized by rapid information acquisition and processing: (1) Information display for improved situation awareness - makes critical information accessible to all (i.e., improves externalization and enhances working memory); (2) Automatic suggestion for the subsequent actions - akin to an automatic checklist to ensure key steps are executed; (3) Automatic diagnosis - using artificial intelligence to suggest diagnosis and treatment approaches
Information flow, coordination among team members	N/A	N/A

Information flow, coordination among team members, internal/ external representations	"We observed instances where the update uncovered discrepancies between the information resources...bringing to light confusion among the staff and initiating the resolution of these problems. Hence, creating the handover summary had a positive effect on the accuracy of other information resources , including the knowledge of the staff and there was the potential for error as the information had to be compiled from a variety of sources; this was particularly the case with the doctors' book where, for the first handover of the day, all the information had to be written by hand from scratch.	N/A
Spatial layout, information flow, coordination among team members, internal/ external representations	N/A	N/A
Information flow, coordination among team members, communication between patients & providers	N/A	N/A

Sophistication of theory use	Conclusions	Strength of conclusions
Theory Testing/Verification	"*Spatial arrangements* of paper-based patient records were important in supporting cognition and collaboration. Being able to place and arrange records in different ways was an important property of the paper-based records and enabled clinicians to create *cognitive tools* that offloaded memory tasks and supported clinical performance... because the cognitive work was a *collaborative effort* among clinicians that was *distributed* over time and was *represented* in the cognitive tool, it further supported the cognition of the pracitioners. In the design of computer-based records, failing to account for how clinicians use paper-based records in practice could result in the *introduction of new tasks* that increase cognitive workload... and ultimately risk patient safety."	Level 4: conclusions are clear & likely to be true
Theory Application	"DiCOT provides added value to the study of OR work through its focus on information propagation and transformation, as well as the roles of people and artifacts in supporting communication and situation awareness." Additionally, it serves as a useful method for identifying possible pitfalls with the OR distributed cognitive system. Compared to contextual inquiry, the DiCoT analysis was what revealed areas for improvement. "The principles of DiCoT application require an in depth understanding of Dcog (which has implications for research). "	Level 3: results can probably be used to draw stated conclusions
Theory Testing/Verification	The characterization of DCog in the PED "enhances our understanding of the cognitive dynamics underlying error in this system, and will serve to guide future research on error management" both in the PED and in other, similar clinical care environments. "Understanding the components and limitations of the cognitive system... allows for the ecologically sensitive design of information resources that enhance the natural flow of information." Likewise, the design of systems to manage error requires understanding the DCog processes by which these errors occur.	Level 4: conclusions are clear & likely to be true
Theory Generation	"Current documentation tools in the ICU are not sufficient to capture the interdisciplinary coordination and verbal communication of goal-directed actions that occur during, and between, ICU interdisciplinary morning rounds." "EHR documentation is often not up-to-date and is not effieficent for clinicians to retrieve." "These challenges result in further reliance on verbal information exchange which may lead to interruptions, errors of ommision, and information loss."	Level 3: results can probably be used to draw stated conclusions

Theory Application	"Electronic documentation tools that, in real time, capture information that is currently verbally communicated may increase the effectiveness of communication." "The large amount of information that is verbally exchanged is evidence that clinicians have not harnessed the EHR tools available for their maximum use of information exhange." This may be because "current documentation tools...may not be sufficient to capture the interdisciplinary communication of common goals that occur during, and in between, ICU interdisciplinary morning rounds." These deficits are important to acknowledge because "verbal information exhange is subject to information loss." "The development of EHR communication tools should target verbal information exchange and free text documentation. "Future research should aim to further understand and meet the need for EHR information and communication tools to support verbal information exchange in the ICU in real time."	Level 3: results can probably be used to draw stated conclusions
Theory Application	"Nurses' and physicians' handoff artifacts in the ICU were highly structured and allowed for annotations and note taking during handoff and patient care activities...Clinicians used these documentation tools to support individual cognitive processes as well as communication and collaboration within a discipline." However, despite a high degree of overlap between nurse and physician handoff artifacts, the use of siloed, discipline-specific handoff documentation on paper-based artifacts and computer based systems not integrated with the EHR can be a significant source of error. The "future development and evaluation of semi-structured patient-centered handoff tools with discipline specific views customized for specialty settings may support handoff communication and patient safety." Tools should utilize a structured-narrative design and be customized according to specialty units to facilitate the establishment of common ground.	Level 3: results can probably be used to draw stated conclusions
Theory Dropping	This study "advances the current body of knowledge by making explicit relevant cognitive processes involved during the intraoperative phase of cardiac surgery from the perspective of multiple OR team members." "By displaying the research findings in an interactive dashboard, we provide trainees with new knowledge in an innovative fashion that could be used to enhance learning outcomes." The approach used in this study, "can be used to deeply understand the cognitive factors underlying adverse events and error in the OR"	Level 3: results can probably be used to draw stated conclusions
Theory Application	1) "We have proposed a novel framework: the DiCoT concentric layers (DiCoT-CL) framework, which..advances analytical support for Dcog studies that aim to evaluate the design and use of medical devices in practice." 2) "For researchers interested in medical device assessment and development this encourages reflection on the device's coupling to different layers of the system, reflection within and between levels, and reflection on the scope and coverage of the analysis."	Level 3: results can probably be used to draw stated conclusions

Theory Application	"Safety is constructed through the co-evolution of sociotechnical structure and agency whereby structure shapes and influences people's behaviour and people reproduce and create structures." "Studies of everyday safety can explore interactions between four points of a sociotechnical structuration model: structure, agency, and satisfactory and unsatisfactory performance." "Our findings highlight how safety in infusion practices depends on the unfolding interactions of a complex sociotechnical system. Factors across the system, both close to and far from infusion practice, and involving the interplay between structure, agency and performance variability within the system, can all affect safety."	Level 3: results can probably be used to draw stated conclusions
Theory Application	"By describing how the system is configured and embedded in ICU IV infusion practice, we have identified a number of benefits that are specific to the closed-loop documentation system, as well as evidence of how it helps enhance properties of DCog for staff on ICU. "However, the study has also highlighted ways in which these new ways of working bring new issues and vulnerabilities that need to be managed."	Level 3: results can probably be used to draw stated conclusions
Theory Application	"Our study confirms that a cross-boundary distribution of cognitive work can be negatively affected by professional or organizational cultures struggling to protect their professional identity"	Level 4: conclusions are clear & likely to be true
Theory Application	1) "Distributed prospective memory can be used to investigate how agents in a system interact to remember future intentions." 2) "Results... can be used to enhance nurse's awareness of unsupported task that are more likely to be forgotten and give the possibility to gain metaknowledge of how to successfully manage prospective memory demands." 3) "Results show that theories based in individual cognition explained a significant proportion of the variance of the observed resumption lags in the main model." 4) "The analysis of nurses' behavioral strategies shows that nurses' behavior eased or even prevented the memory demands of task resumption distributing prospective memory demands."	Level 3: results can probably be used to draw stated conclusions

Theory Application	"The regression model revealed that longer interruptions and a change in the nurse's location hamper task resumption. In addition, the regression submodels indicated that finishing a primary task step before attending an interruption eases the resumption of computer-based documentation tasks and that the resumption is unaffected by the interruption length." "Nurses frequently used strategies that distribute memory demands into the immediate environment and therefore diminish or prevent demands on individual cognition." "The results relating to behavioral strategies show that it is necessary to extend research beyond the individual mind and include the adaptive and discretionary use of artifacts and DCog to understand the management & effects of interruptions."	Level 3: results can probably be used to draw stated conclusions
Theory Application	"As the initial step of patient care in the ED, registration must be both efficient and accurate. Failure to meet both of these goals can lead to adverse outcomes. Slow registration can impede care by delaying processing of orders of tests or delaying access to existing medical records... Inaccuracy in information can lead to a myriad of errors, including lack of access to existing medical records, inability to contact a patient after discharge and even implementation of an incorrect treatment regimen with dangerous consequences to the safety of the patient." "Errors often occur, not as a result of the failure of a single entity within the system, but as a result of the breakdown of the system. These failures have many underlying causes, including but not limited to the heavy patient volume, the need to multitask and the inevitable tendency to work around the established procedural codes/ Whereas in some cases technological solutions can improve the situation, in others, they could very well lead to more errors.	Level 4: conclusions are clear & likely to be true
Theory Application	DCog and cognitive ethnography can be productively applied to effectively explain and possibly predict" certain consequences associated with a copmuterized physician ordering entry system. Designers of such technologies would do well to understand their product as a component of an activity system in order to mitigate unintended consequences, to have their products adopted by users, and to make their products more useful to actors in the system.	Level 3: results can probably be used to draw stated conclusions
Theory Testing/Verification	The authors used DCog to investigate distributed planning for the provision of surgical tools. They concluded that "distributed planning" refers to those features of an activity system that systematically organize actions into the future. We highlight two distinct aspects of distributed planning: preparatory configuration and active replanning. Preparatory configuration is accomplished in presurgery setup of tools that enables streamlined action according to an expected sequence, yet also allows for alternative paths to the intended goal. Replanning is dynamic reconfiguration of plans in the face of unforeseen events, using available resources to create new paths to achieve goals. Replanning is an essential activity for accommodating dynamic and uncertain situations. Analyses that employ the framework of DCog make clear the need to redefine error and the need to develop interventions that can simultaneously optimize performance at multiple levels of analysis.	Level 4: conclusions are clear & likely to be true

Theory Testing/Verification	"We identified a set of six types of exchange between surgeon and cardiologist and found them to facilitate specific functions of this activity system, which we named: direction, goal-sharing, status, alert, explanation, and problem-solving." "These functions enable robust system performance through (a) making the current situation clear and mutually understood, (b) making goals and envisioned future situations clear and thereby anticipated, and (c) expanding upon the activity system's knowledge base through discovery and sharing of experience."	Level 4: conclusions are clear & likely to be true
Theory Application	"We have identied the presence of a ventilator, the number of intravenous drips, and the number of medications as visually available factors that predict patient acuity." "We propose that these, as well as other visually available physiological parameters, should be used to construct a cognitive heuristic to prioritize automated patient alarms." The authors also recommended that these heuristics should be taken into account when creating future automated patient alarm systems. These future systems should: allow nurses to better assess acuity; help nurses identifiy unimportant alarms; and establish a better balance of trust in alarm systems.	Level 3: results can probably be used to draw stated conclusions
Theory Application	"We found that poor information flow and limited scaffolding expose hospital staff to contagions. We hypothesize that appropriate use of digital signs next to patient room doorways may mitigate these problems, while improving documentation compliance."	Level 5: conclusions are unequivocal
Theory Generation	"A more ecological approach to the development, design and implementation of EHRs has considerable potential. Hence, when developing and designing the systems, it is important to pay attention to the overall socio-technical system of which they are going to be part."	Level 4: conclusions are clear & likely to be true

Theory Conversation	"The information seeking process [was] exploratory and iterative. Additionally, the distributed nature of information resulted in the information seeking process driven by the local organization of information: physicians optimized their information seeking process by depending on specific sources for specific types of information and their choices were often driven by the information gain from these sources." "A process of local optimization drove the information seeking process: physicians utilized information that maximized their information gain even though it required significantly more cognitive effort."	Level 5: conclusions are unequivocal
Theory Conversation	"Safety, especially in acute care settings such as maternity care, is an emergent property of complex systems: enduring high performance is likely to be dependent on reshaping the multiple, interacting features of systems in a way that enables the reproduction of desired outcomes." "This study enhances understanding of what makes a maternity unit safe, paving the way for better design of improvement approaches. It also advances the debate on quality and safety improvement by offering a theoretically and empirically grounded analysis of the interplay between interventions and context of implementation."	Level 4: conclusions are clear & likely to be true
Theory Application	"Strategies to improve shared situational awareness are needed to improve teamwork, patient flow and resource efficiency. Tools need to be evaluated regularly to ensure their continuous usefulness."	Level 5: conclusions are unequivocal
Theory Application	"Deeper understanding of the purpose of interruptions in critical care can help to distinguish between interruptions that require face-to-face conversation and those that can be eliminated with informatics solutions. The proposed taxonomy of interruptions and representational analysis can be used to further advance the science of interruptions in clinical care."	Level 4: conclusions are clear & likely to be true

Theory Application	5 requirements for an EHR-generated patient summary were established: "1) the importance of selecting and formatting the data, 2) the value of writing the data; 3) the importance of spatial, proximity and chronology data organization, 4) the role of visual cues that are personally meaningful to the individual nurse, and 5) the value of being able to see the care needs of an individual patient and an entire patient care assignment to the organization and prioritization of the nurse's work." "Customizable artifacts needed" - "A 'one-size-fits-all' patient clinical summary is likely to result in suboptimal data content (i.e. extraneous data in the context of needed and missing data), and suboptimal data visualization (i.e., data proximity, spatiality, and chronology) to support data perception and critical thinking needs as determined by internal knowledge representations needs of the individual nurse."	Level 3: results can probably be used to draw stated conclusions
Theory Application	"Purposeful improvement occurs during daily work and highlights two related forms of integration that occur during this activity: integration of individual competencies and integration of individuals and their social and material context." "Individuals construct their context for purposeful improvement, adapt and reinforce the improvement during its performance and purposefully build best practice through systematically sustaining improvements in daily clinical work."	Level 3: results can probably be used to draw stated conclusions
Theory Application	Understanding the origin and nature of the physical artifacts relies on deep and sustained observation of the groups and activities they support in order to derive their meaning. This basis will support the creation of pilot computer-supported artifacts that are based on work domain characteristics.	Level 4: conclusions are clear & likely to be true
Theory Positioning	"Pediatric fellow ICU handoff content varies but exchanges conform to Grice's maxims by demonstrating high context sensitivity, compact reference, gestures, and stylized expressions." "Hand-offs focus on what is uncertain, are complex and flexible in their structure, necessarily variable in their content, and take multiple forms."	Level 3: results can probably be used to draw stated conclusions
Theory Dropping	"The research team's activity in Year 1 confirmed that clinicians use multiple processes that are captured in the macrocognitive activities mentioned earlier."	Level 3: results can probably be used to draw stated conclusions

Theory Application	Documents (like the Kardex) may be "employed more often than others because they are considered a transient resource and are updated more frequently than any other, making them the most current source of information." "It is possible that hand notes were not commonly used by nurses in this study due to their informal nature or the fact that they are updated less frequently than official documentation." "It is possible that the length of oral reports is influenced by the incorporation of artifacts which may actually lengthen the duration of handoffs thereby hindering their intended efficiency."	Level 3: results can probably be used to draw stated conclusions
Theory Conversation	It is "important to ensure that the organization imposed on the healthcare professionals participating in the medication use process is coherent, i.e. that the distribution of the control of the medication process is consistent with the distribution of tasks and with the resulting knowledge of each actor."	Level 3: results can probably be used to draw stated conclusions
Theory Application	The findings of the study confirm that DCog can be a methodology of choice for studying healthcare work: a high level of collaboration was found among nurses; artefacts were found to play a major role in supporting and coordinating work; and the (dynamic) configuration of the physical environment was found to influence work. These properties imply that an approach which views cognition as being distributed throughout a system, rather than being only in the minds of individuals, is needed to effectively analyse human-computer interactions in such a setting	Level 4: conclusions are clear & likely to be true
Theory Application	"We identified four types of errors that are unique to teamwork in trauma resuscitation domain: (1) communication errors, due to information loss; (2) vigilance errors, due to failing to intercept and prevent others' errors; (3) interpretation errors, due to the effect of sporadic, asynchronous data gathering and the current mode of collective memory operation on diagnostic reasoning; and (4) management errors, due to the team leader losing track of the progress of multistep procedures." "We concluded that the key role of technology would be to externalize the situational information for reliable storage and easy access. The two most critical information structures in trauma teamwork that need externalization include: (1) evidence gathered up to the present; and (2) procedure steps that were successfully completed up to the present."	Level 4: conclusions are clear & likely to be true
Theory Application	This exploratory study identified how and to what extent EHR support and enable handover. The study identified three EHR use modes and contributes to an increased understanding of nurses' perception on the use of EHR for handover and how it affects their handover performance.	Level 3: results can probably be used to draw stated conclusions

Theory Application	"We have reported findings from an in use, in situ evaluation of two cognitive artifacts to argue for the value of such an endeavor and to reflect on and articulate the issues that usability practitioners should seek to uncover during such evaluations. In use, in situ evaluation offers the opportunity of revealing new insights about artifact use and design flaws, but different methods are needed to achieve this. This poses a challenge to develop new techniques to support the usability practitioner in the future."	Level 4: conclusions are clear & likely to be true
Theory Positioning	"Our research calls for future studies to pay close attention to details in how artifacts are used in support of collaborative work...The needs of users change in response to not only their preferences but also changes in task requirements...users are very inventive in exploiting tools for coordination. Providing ways for users to improvise is an important function for public displays"	Level 3: results can probably be used to draw stated conclusions
Theory Application	"The overall patterns [of artifact use] were fluid and flexible, with the primary focus on unmediated, direct interaction." "The use of multiple theoretical perspectives provides deeper understanding of the complicated social and informational processes that occur during rounds. From a practical point of view, rounds are both an important communication forum as well as a tool to improve patient care. Through the use of computerized tools and educational interventions, we may achieve the goal of improving communication."	Level 3: results can probably be used to draw stated conclusions