
Teamwork in the operating room arena
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Overview

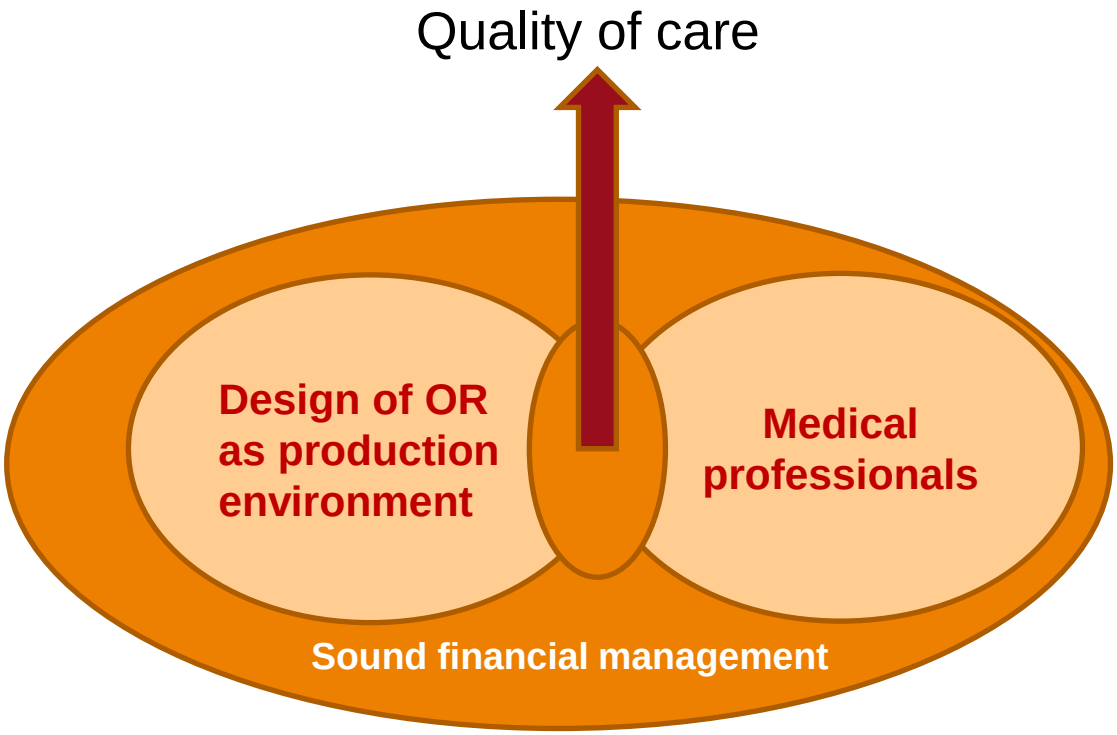
- Why teamwork in high-risk medical environments
- Capturing team processes in the wild
- Two models of teamwork
- Case study in paediatric cardiac surgery: Social Network Analysis
- Conclusions and recommendations


What keeps hospitals' boards of directors awake?

- Possible reputation damage as a result of patient safety and quality issues
- Challenges regarding the sustainable deployment of people and resources (as a result of shrinking budgets) that have to lead to sound financial management

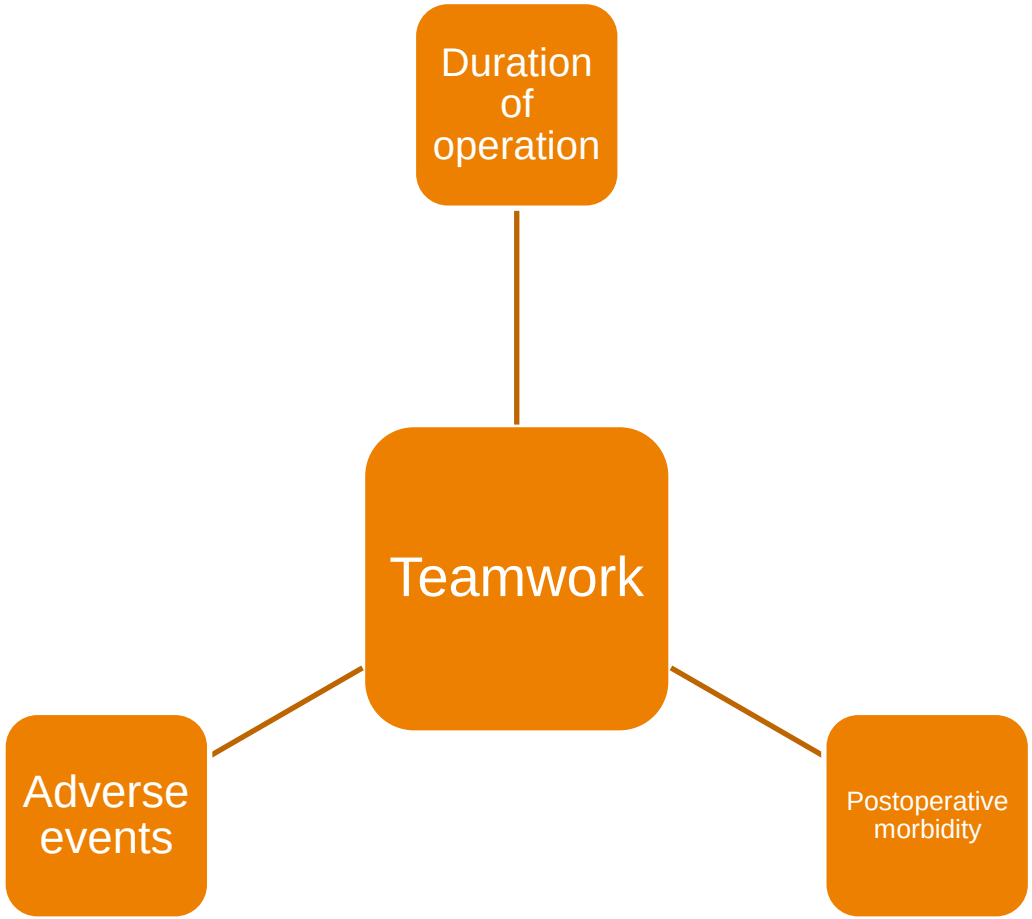
- These worries force Boards of Directors to:
  - Engage in pro-active safety management
  - Being externally visible and recognized as providers of excellent quality and safety of care
  - Being good employers

Most important internal issue:

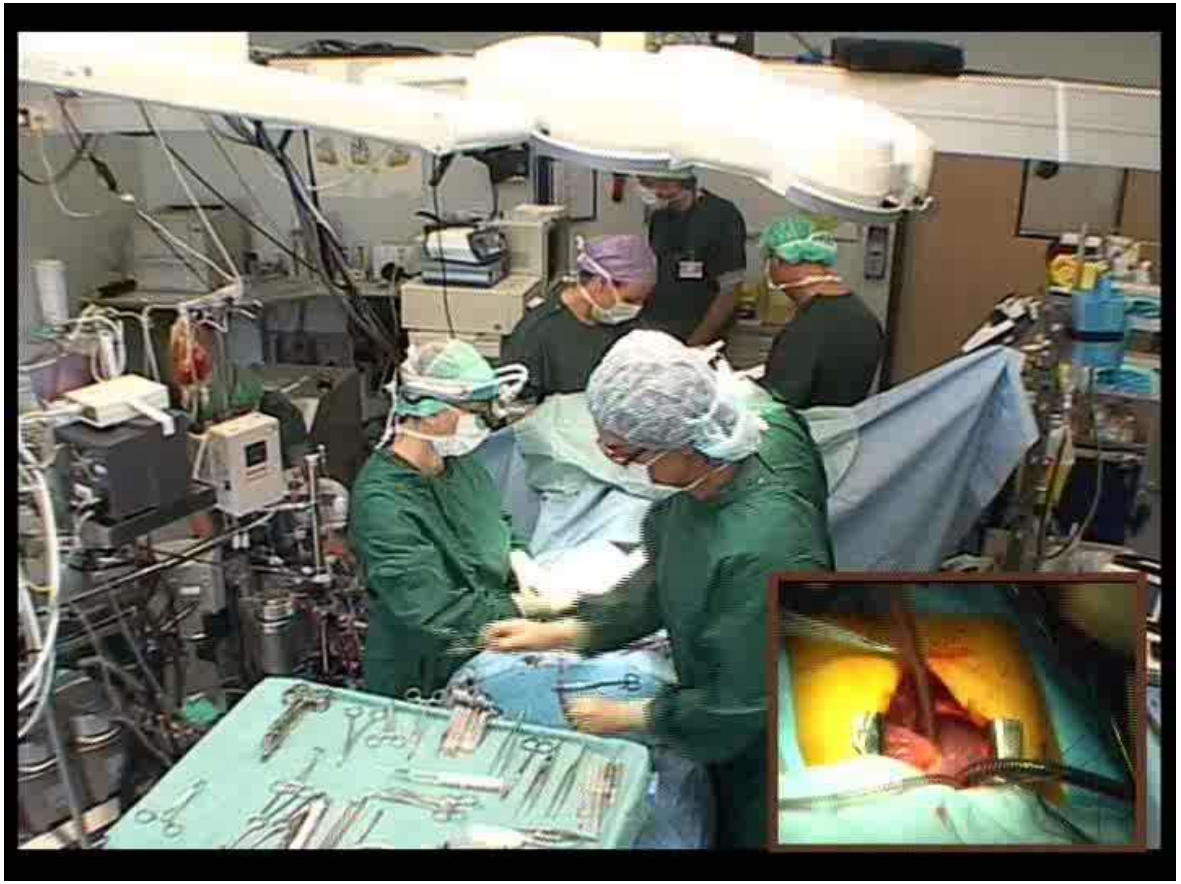


External: quality of care, financially sound, attractive workplace

Is quality of care enabled by teamwork?



A snapshot of “routine” teamwork in paediatric cardiac surgery



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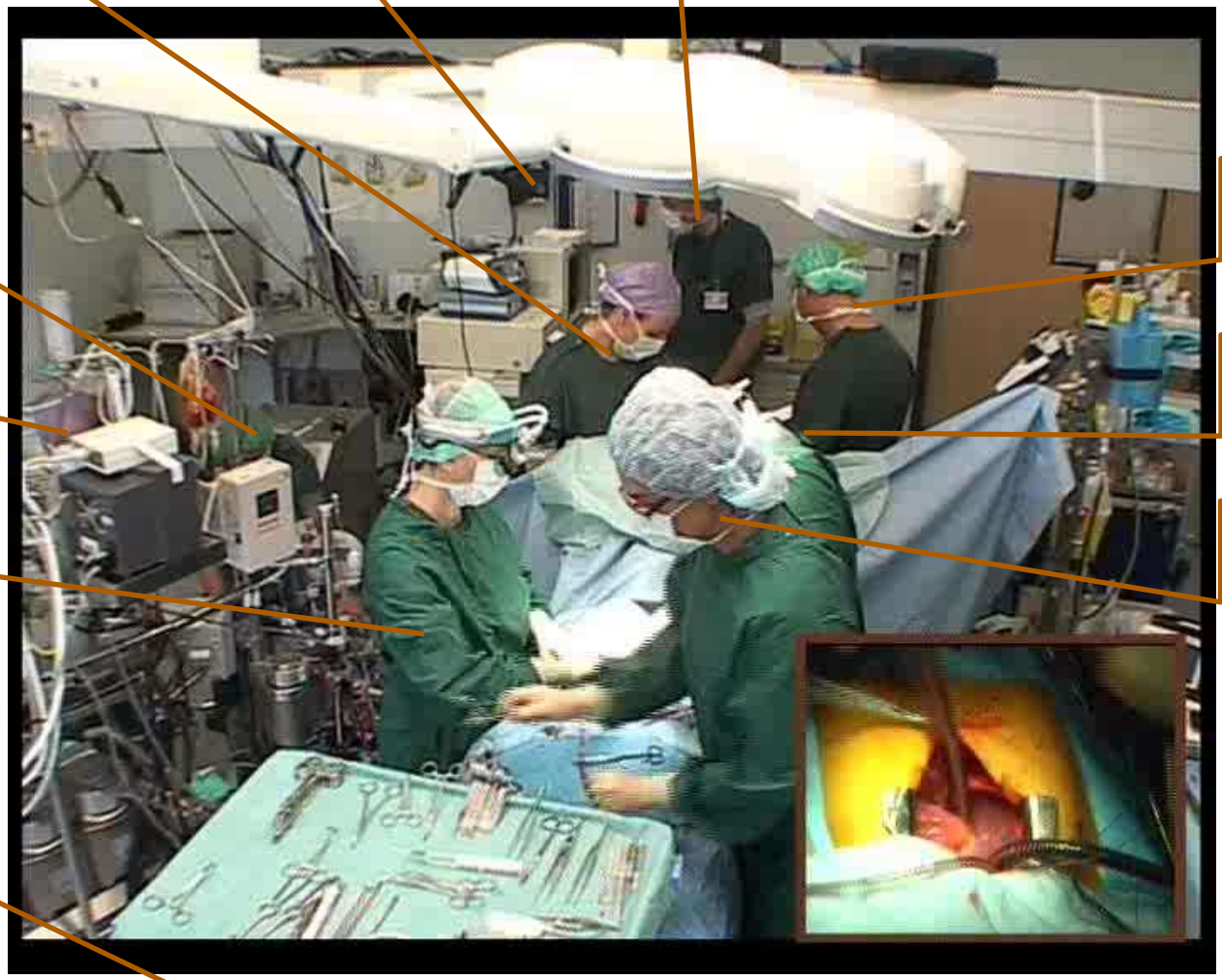
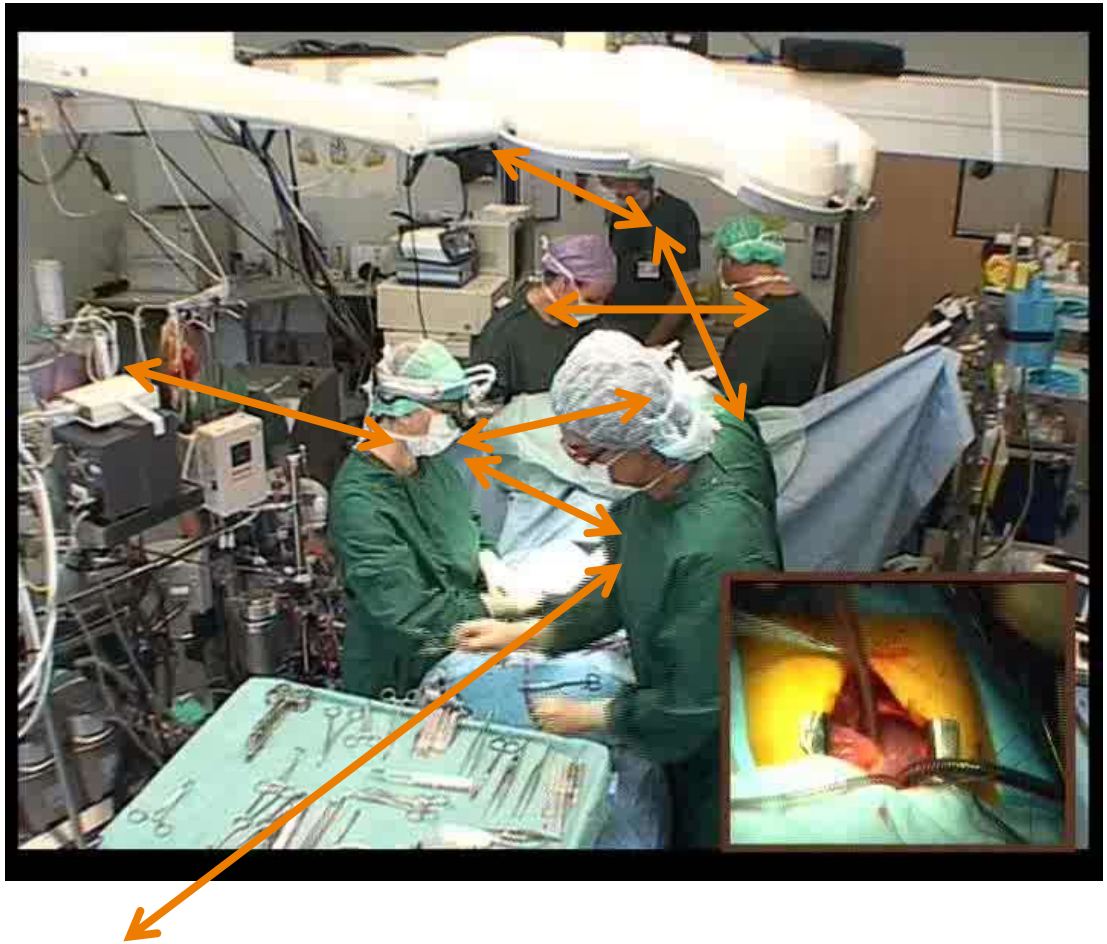
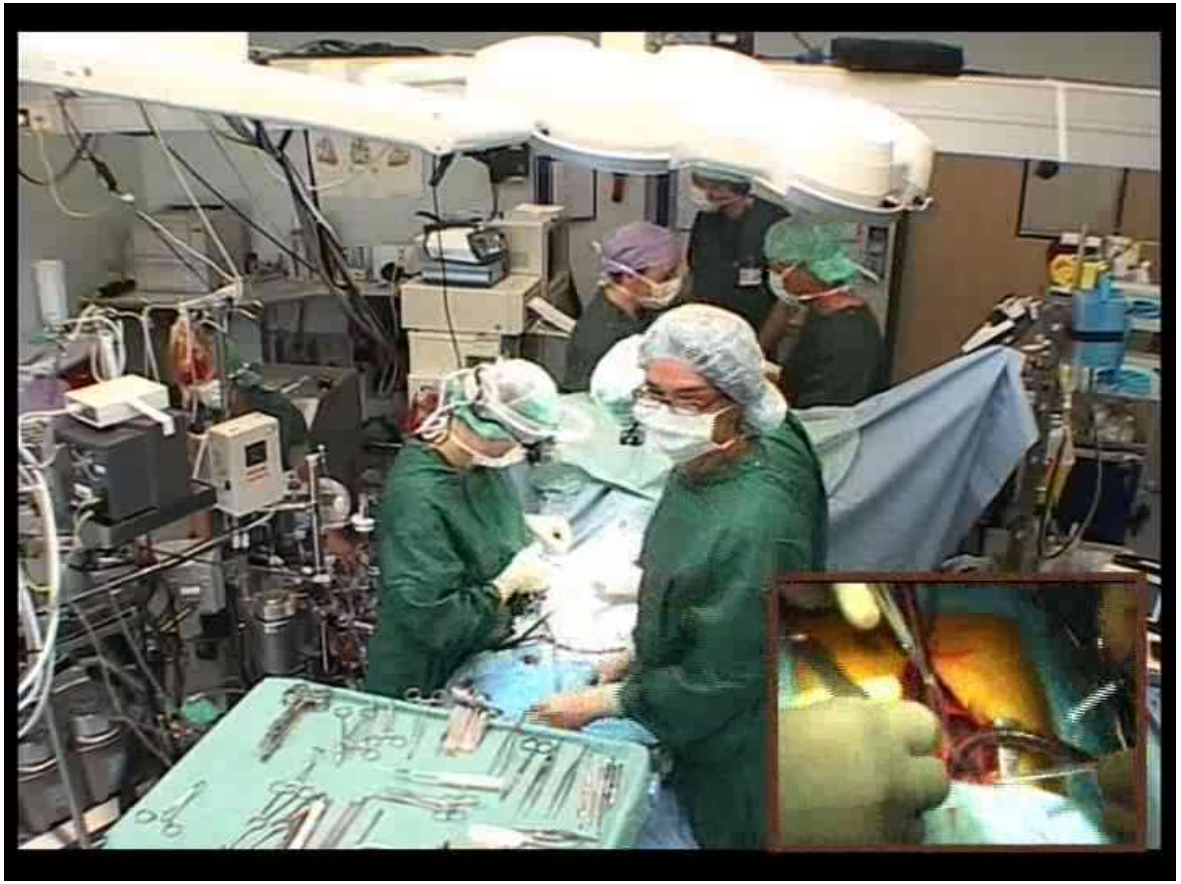
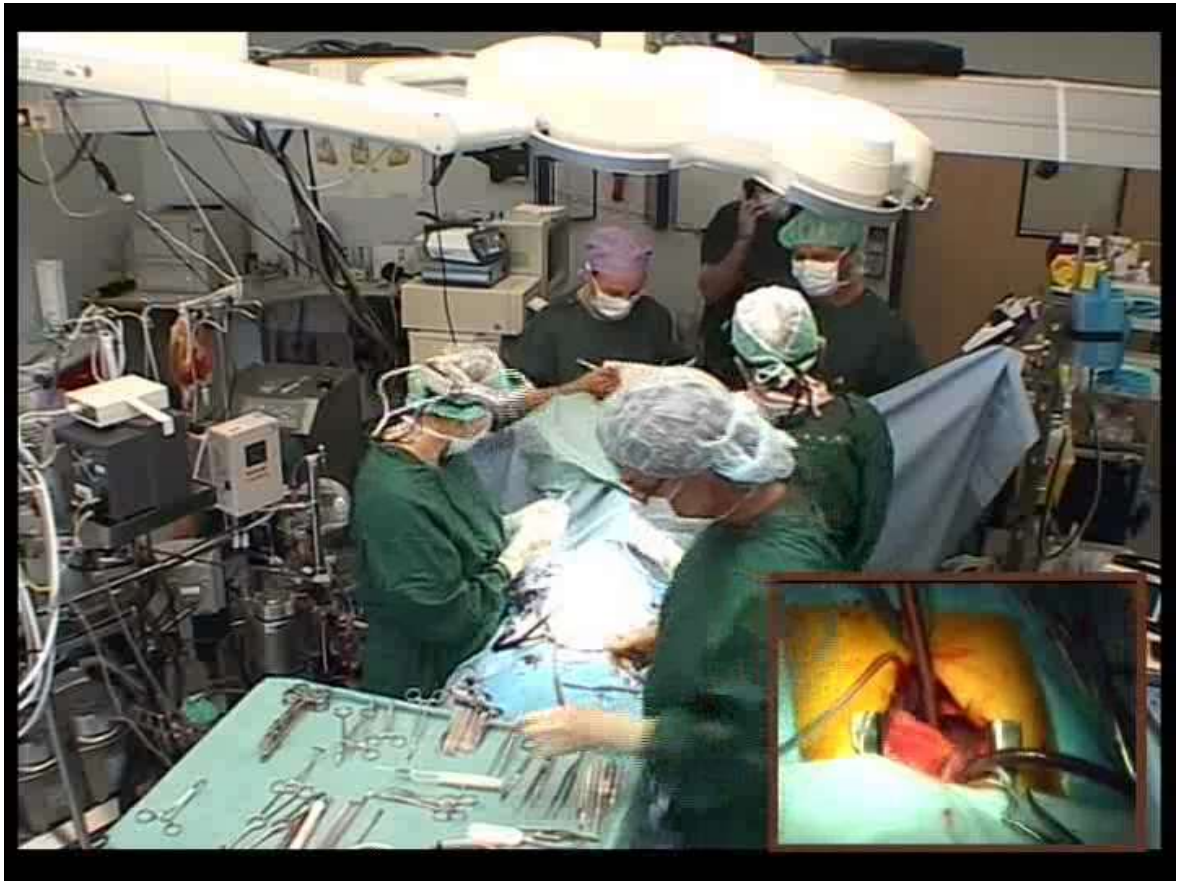
Relevant actors

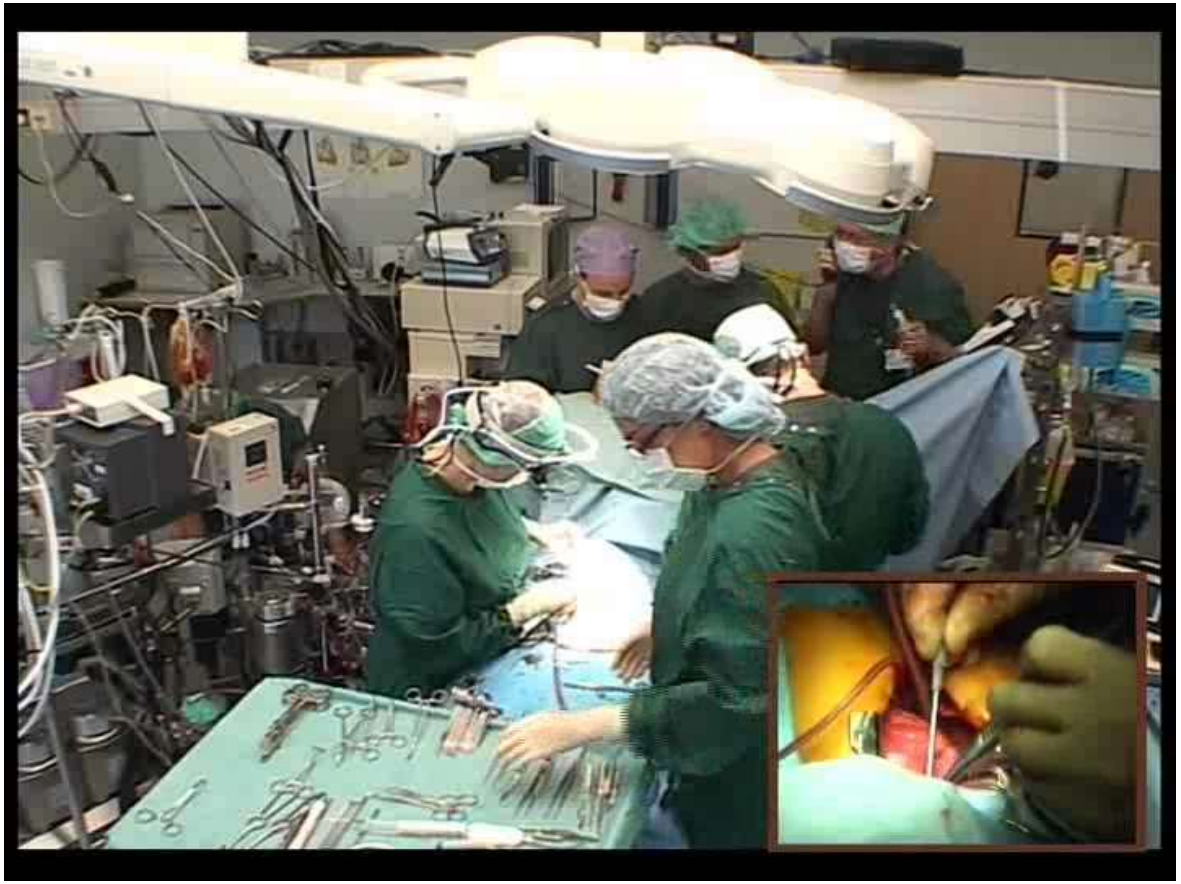


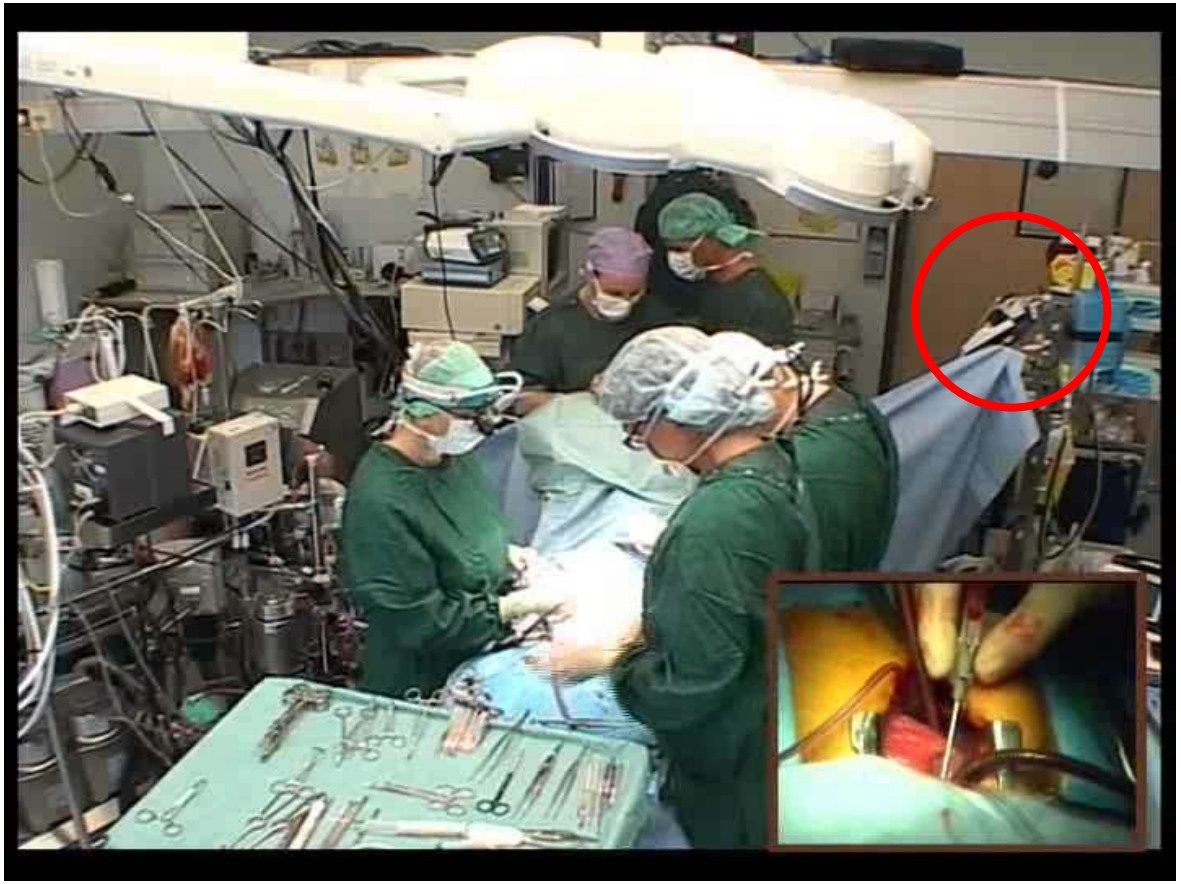
Patterns of interaction











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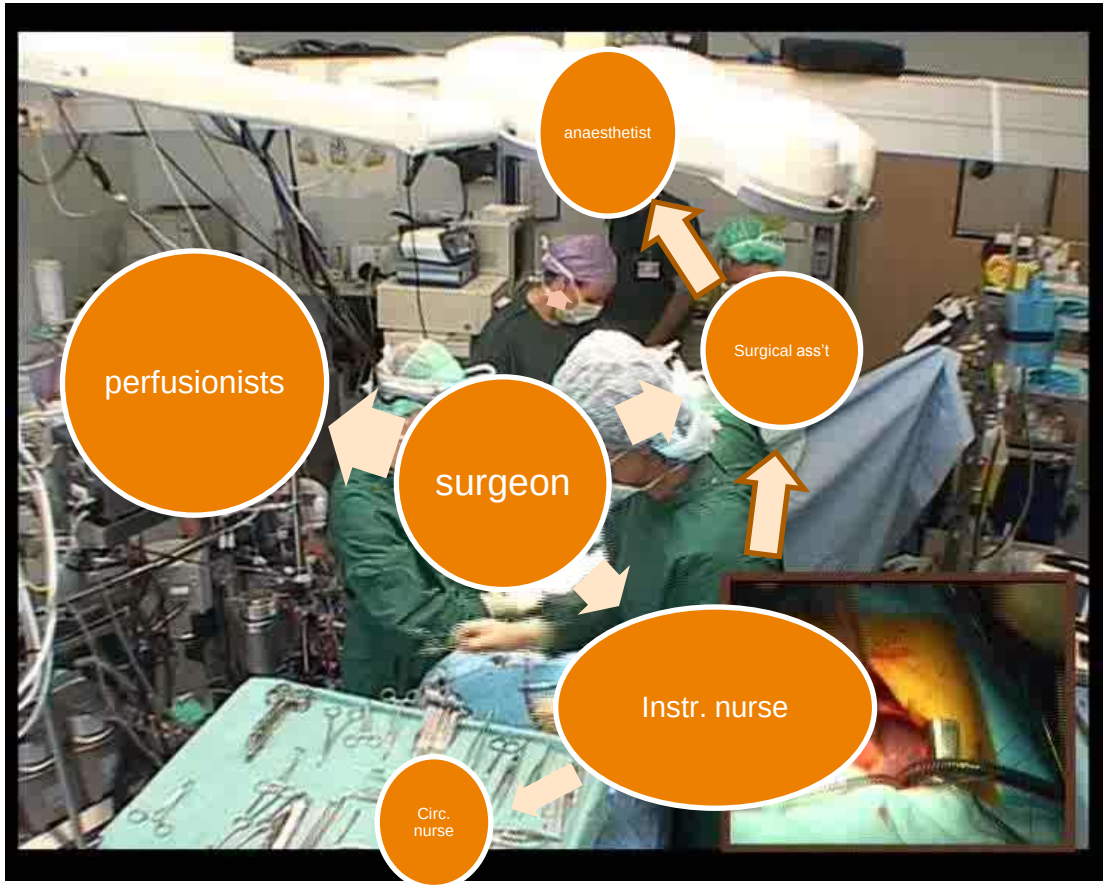
Patterns of interaction: high centrality of surgeon



Observing teamwork in the wild

- There's more going on than meets the eye
  - Many parallel processes going on at the same time
  - Focus of attention of participants and observers is limited

- The team is a nearly-decomposable system (Simon, 1962)
  - It is not completely immune to external factors (phone calls, logistics), but may be considered in a relatively isolated fashion
  - One non-routine event does not necessarily affect the team as a whole
  - Within the team, there are subteams formed by patterns of communication, depending on the stage of the surgical procedure

Examples of team assessment methods

- NOTSS (Non-Technical Skills for Surgeons, University of Aberdeen, Scotland)
- ANTS (Anesthetists' Non-Technical Skills, University of Aberdeen, Scotland)
- NOTECHS (Non-Technical Skills Scale, Oxford University, Oxford)
- OTAS (Observational Teamwork Assessment for Surgery; Imperial College, London)

General structure of each tool

- There are generally a limited (4-6) number of high-level behavioral categories (e.g., leadership, situation awareness, decision making, coordination, back-up behavior). These categories are sometimes referred to as ‘dimensions’ or ‘skill categories’
- The high-level categories are subdivided into ‘elements’ or ‘subcategories’
- For each element, ‘good’ and ‘poor’ behaviors are described (sometimes referred to as ‘positive’ and ‘negative’ modifiers)

From: Non-Technical Skills for Surgeons (NOTSS)

Category	Elements
Situation Awareness	• Gathering information • Understanding information • Projecting and anticipating future state
Decision Making	• Considering options • Selecting and communicating option • Implementing and reviewing decisions
Communication and Teamwork	• Exchanging information • Establishing a shared understanding • Co-ordinating team activities
Leadership	• Setting and maintaining standards • Supporting others • Coping with pressure

NOTSS System Rating Options

Rating Label	Description
4 – Good	Performance was of a consistently high standard, enhancing patient safety; it could be used as a positive example for others
3 – Acceptable	Performance was of a satisfactory standard but could be improved
2 – Marginal	Performance indicated cause for concern, considerable improvement is needed
1 – Poor	Performance endangered or potentially endangered patient safety, serious remediation is required
N/A – Not Applicable	Skill was not required or relevant in this case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Hospital ..... Trainer name ..... Date .....

Trainee name ..... Operation .....

Category	Category rating*	Element	Element rating*	Feedback on performance and debriefing notes
Situation Awareness		Gathering information		
		Understanding information		
		Projecting and anticipating future state		
Decision Making		Considering options		
		Selecting and communicating option		
		Implementing and reviewing decisions		
Communication and Teamwork		Exchanging information		
		Establishing a shared understanding		
		Co-ordinating team activities		
Leadership		Setting and maintaining standards		
		Supporting others		
		Coping with pressure		

* 1 Poor; 2 Marginal; 3 Acceptable; 4 Good; N/A Not Applicable

1 Poor	Performance endangered or potentially endangered patient safety, serious remediation is required
2 Marginal	Performance indicated cause for concern, considerable improvement is needed
3 Acceptable	Performance was of a satisfactory standard but could be improved
4 Good	Performance was of a consistently high standard, enhancing patient safety; it could be used as a positive example for others
N/A	Not Applicable

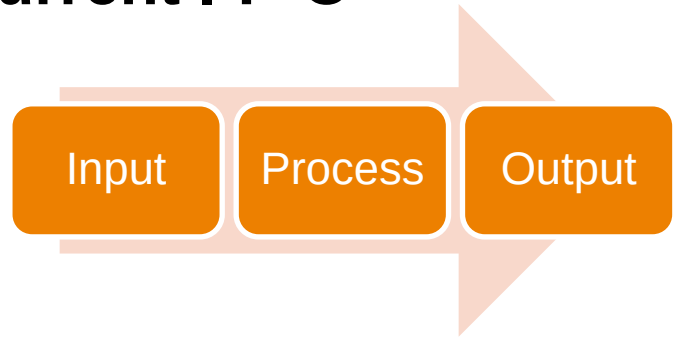
Questions to be asked of each tool

- **When** are categories scored and ratings provided: during the operation or afterwards?
- At what **sampling rate** are categories scored: second, minute, hour?
- At what **grain size** are categories scored: each communication behavior, each operative phase, each subteam?
- Are example behaviors **unambiguously defined** and can they be scored with high inter-rater reliability?
- How are observers **trained** in using the tool: on videos, real-life operations, simulated teamwork behavior, by classroom instruction?

Strengths and limitations of teamwork assessment tools

- **Strengths:**
  - Allows teamwork behaviors to be evaluated and discussed by the team itself
  - Can be used in team training environments (e.g., with patient simulators) to record progress in teamwork behaviors over time
  - Can be used to assess quality of teamwork by external regulatory body (e.g., Inspectorate for Healthcare)
- **Limitations:**
  - Time-consuming and expensive (requires a lot of training)
  - Categories are not intuitive to most team members with a non-human factors background
  - Ratings tend to be subjective and subject to outcome bias

Underlying assumptions of current I-P-O teamwork models



- Teamwork is a property that a team can have to a certain degree
- It may be decomposed into elements such as situation awareness, leadership, and backup behavior
- Patient outcome is a linear function of teamwork: The more you have of it, the better it is (“more teamwork leads to higher levels of patient safety”)

Surgical team behavior and patient outcome

- Previous research: good teamwork associated with shorter duration of operations, fewer adverse events and lower postoperative morbidity
- Effect sizes medium to large (Schmutz & Manser, 2013)

- Some serious incidents in the field of pediatric cardiac surgery have been attributed to poor team processes (Bristol, Winnipeg)

- Drawbacks of previous studies:
  - Link between team processes and patient outcome problematic
  - Observations of teamwork possibly influenced by hindsight bias: cause-and-effect reverse of what most people believe

Some surprising findings[1]

- No association between teamwork and outcome
  - Exception: correlation (inverted U-shape) between surgical cooperation and patient outcome
- No association between teamwork and non-routine events
  - Exception: during cardiopulmonary bypass, positive association between surgical decision making and non-routine events
- Mental and physical preparation beforehand was not predictive at all of patient outcome; questionnaire immediately afterwards on unexpected events and team processes only predicted 30% of the variance in 30-day postoperative outcome

[1] Schraagen et al. (2011). A prospective study of paediatric cardiac surgical microsystems: Assessing the relationships between non-routine events, teamwork and patient outcomes. Br Med J, 20, 599-603

Shared Cognition versus Interactive Team Cognition[1]

- Teamwork is only part of the many contributing factors determining patient outcome (next to complexity, individual technical skills, patient factors and ‘chance’)
- Teamwork is not a monolithic entity, a property that a team either has or does not have: it is highly context-dependent (e.g., depending on the phase of the surgical procedure)
- A team itself is not a monolithic entity: there are differences in the roles various team members play, depending on their specialty (surgeon, anaesthetist, perfusionist, nurse)

[1] Cooke, N.J. et al. (2013). Interactive team cognition. Cognitive Science, 37, 255-285

Team model 1

- Static team entities (‘leadership’; ‘situation awareness’; ‘decision making’)
- Aggregation of individual knowledge
- Context-independent
- Better teamwork leads to patient safety (causal I-P-O model)

Team model 2

- Dynamic team processes
- Analysis at the team level
- Context-dependent
- Better teamwork is an adaptive response whenever patient safety is endangered (emergent model)

Teamwork is not an entity, but an interdependent network

Implications for theoretical frameworks and measurement tools

- Medical teams consist of heterogeneous team members, and their individual knowledge cannot be aggregated to arrive at shared cognition (Cooke et al., 2013)
- Team cognition should be measured and studied at the team level: Use metrics based on communication flow
- Take context into account when studying medical teamwork: team cognition emerges in response to environmental demands

Current study

- Used Social Network Analysis techniques to study communication and coordination at the team level
- Used complexity of the surgical procedure as important determinant for teamwork in a dynamic environment
- Differentiated between the successive phases in a surgical procedure in order to capture context-dependency
- Looked in particular at high-risk transitional processes at the intersection of two successive phases


Hypotheses

- Complex procedures will need more specialized knowledge and will lead to flatter communication structures than less complex procedures (Ahuja & Carley, 1999)
- High-risk phases during the procedure will result in restricted communication among fewer (more senior) team members (cf. Carley, 1992; Carley & Lin, 1995; Xiao et al., 2003)
- Exploratory: does Social Network Analysis capture important team processes?

Method

Live observations of 40 pediatric cardiac surgery cases in clinical setting

Multi-method

Trained human factors observers

Schraagen, J.M.C. et al., (2010). Assessing and improving teamwork in cardiac surgery. *Quality and Safety in Healthcare*, 19: e29, 1-6.

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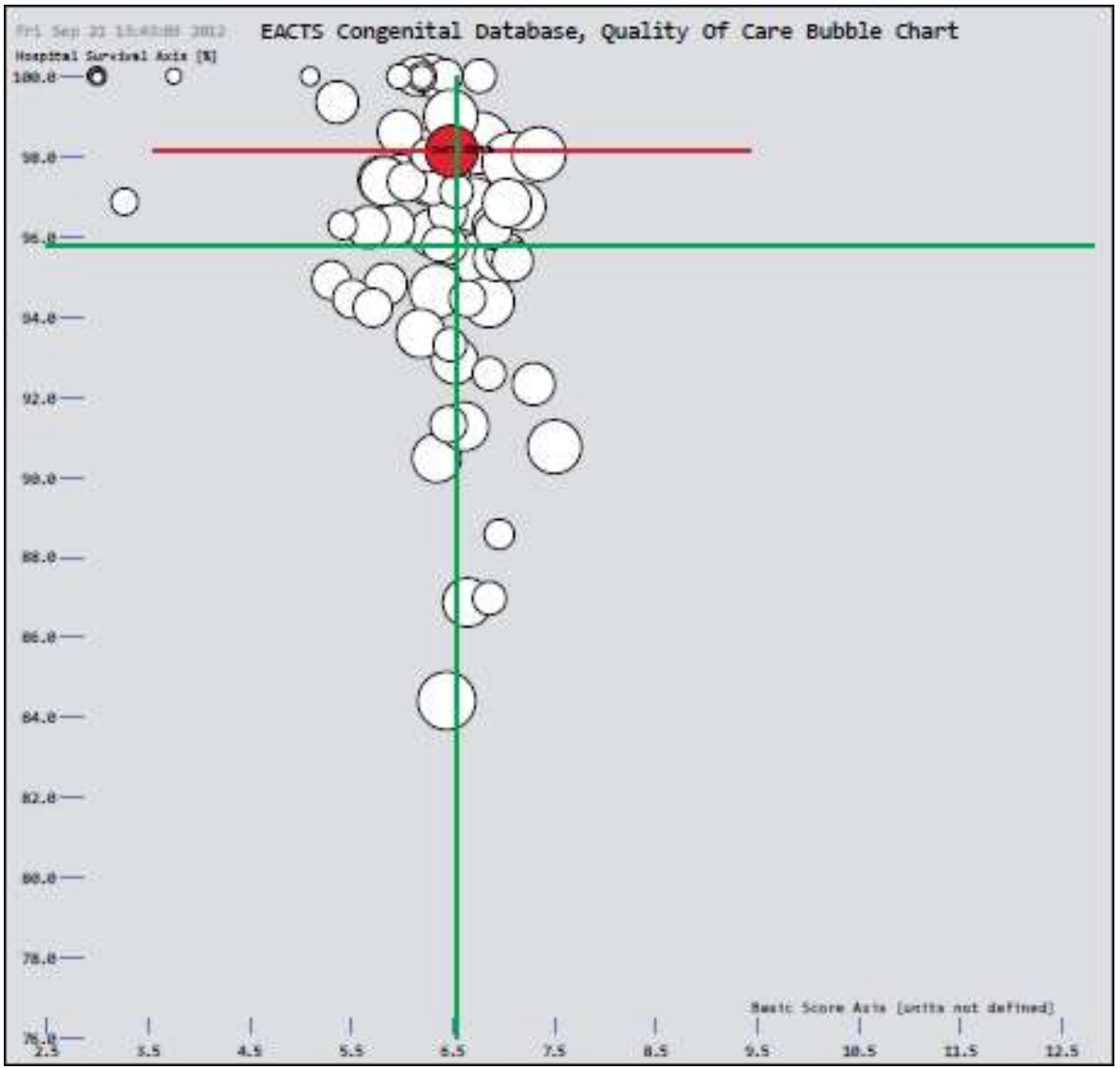
All patients



Source: EACTS Congenital Database, September 21, 2012, www.eactscongenitaldb.org

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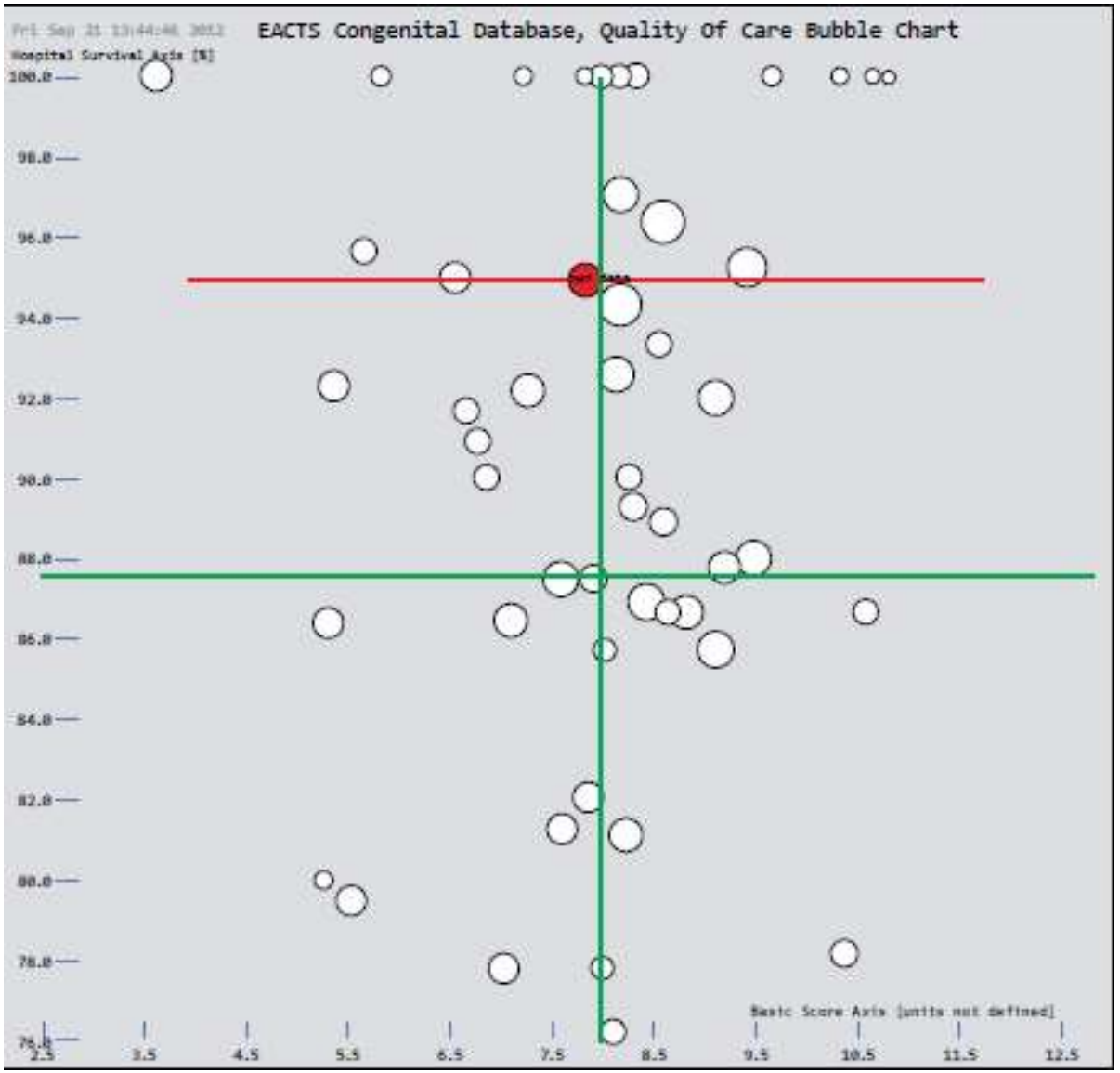
Neonates



Source: EACTS Congenital Database, September 21, 2012, www.eactscongenitaldb.org

Characterizing excellent surgical team behavior[1]

- Based on their results (<30-day mortality rate 1.5%), this is an excellent team
- How does this team achieve this result in terms of communication processes?

[1] Schraagen, J.M.C. (2011). Dealing with unforeseen complexity in the OR: The role of heedful interrelating in medical teams. T*heoretical Issues in Ergonomics Science, 12(3)*, 256-272**.**

Example of filled out behavioral marker system

Time	Actor(s)	From actor	To actor	Notech observation	Category	Score	Epoch
12.50	S1-P1	S1	P1	Where are you now? (35 degrees)	SA1	3	4
12.50	P1-S1	P1	S1	35 degrees	SA1	3	4
12.50	S1-P1	S1	P1	Okay we are ready.	SA1	3	4
12.50	S1-A1	S1	A1	Can we come of HLM? (No we wait until we are some over 35.)	MS	4	4
12.50	A1-S1	A1	S1	No we wait until we are some over 35.	MS	4	4
12.52	S1-A1	S1	A1	Now?	SA1	3	4
12.52	A1-S1	A1	S1	Yes	C	3	4
12.53	A1-T1	A1	T1	HLM is stopped.	SA1	3	5
12.53	P1-S1	P1	S1	Lessen input? (Yes if you can stop filling.)	MS	3	5
12.53	S1-P1	S1	P1	Yes if you can stop filling.	MS	3	5
13.02	A1-P1	A1	P1	Protamine is in.	SA1	3	5
13.05	A3-S1	A3	S1	Arterial line is gone for a while	SA1	4	5

Process flow in PCS during the various epochs

Epoch	Process flow	Domain
1	Patient in surgical holding area.Pre-operative events and medication.Patient transported to OR	Transport to OR
2	Patient in OR. Induction of anesthesia, insertion of lines.Preparing for surgery	Pre-surgery/Anesth. induction
3	Incision. Desection. Canulation	Surgery/pre-bypass
4	Go on cardiopulmonary bypass. Identification of structure. Surgical repair	Surgery/bypass
5	Off CPB. Heparine reversed. Hemostasis	Surgery/post bypass
6	Chest closed. Prepare for move and update ICU. Team leaves with patient to ICU	Transport to ICU
7	Arrival at ICU'. Nurses take over. Anesthetist/surgeon inform ICU attending	Handoff

Focus of current study: Epochs 2 to 5

Epoch	Process flow	Domain
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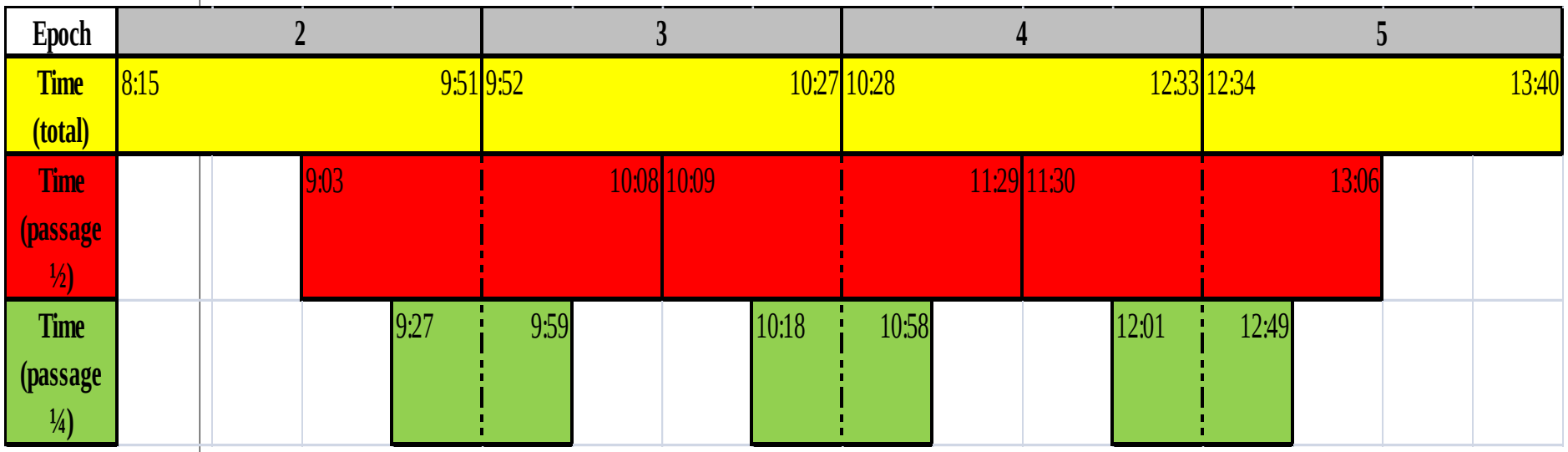
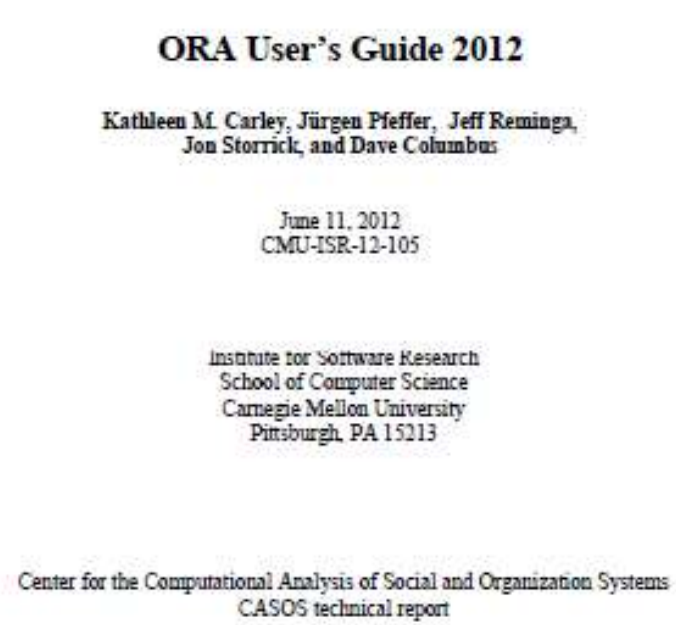
Example of epochs and critical transition periods



Social network analysis



ORA User's Guide 2012

Kathleen M. Carley, Jürgen Pfeffer, Jeff Reminga, Jon Storrick, and Dave Columbus

June 11, 2012
CMU-ISR-12-105

Institute for Software Research
School of Computer Science
Carnegie Mellon University
Pittsburgh, PA 15213

Center for the Computational Analysis of Social and Organization Systems
CASOS technical report

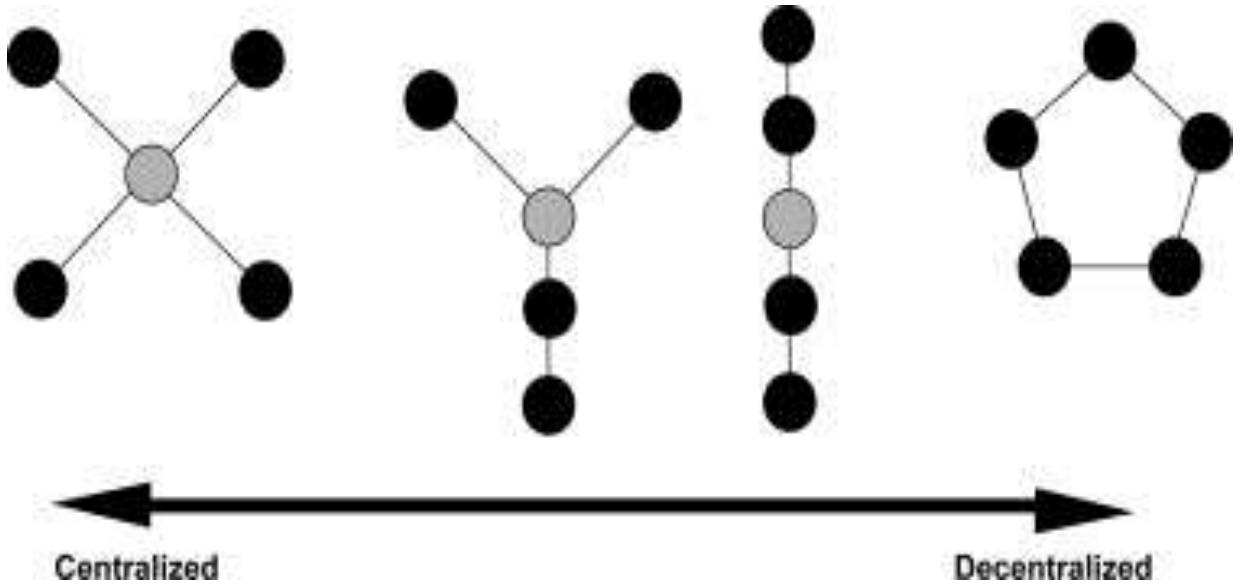
Calculated in ORA (CASOS, Carnegie-Mellon University, Carley et al.)

Compared to teamwork assessment tools:

- Allows for more fine-grained analysis, adapted to specific crucial episodes during the surgical procedure
- Quantification across single procedures
- Analysis at the teamwork level

Examples of social network measures

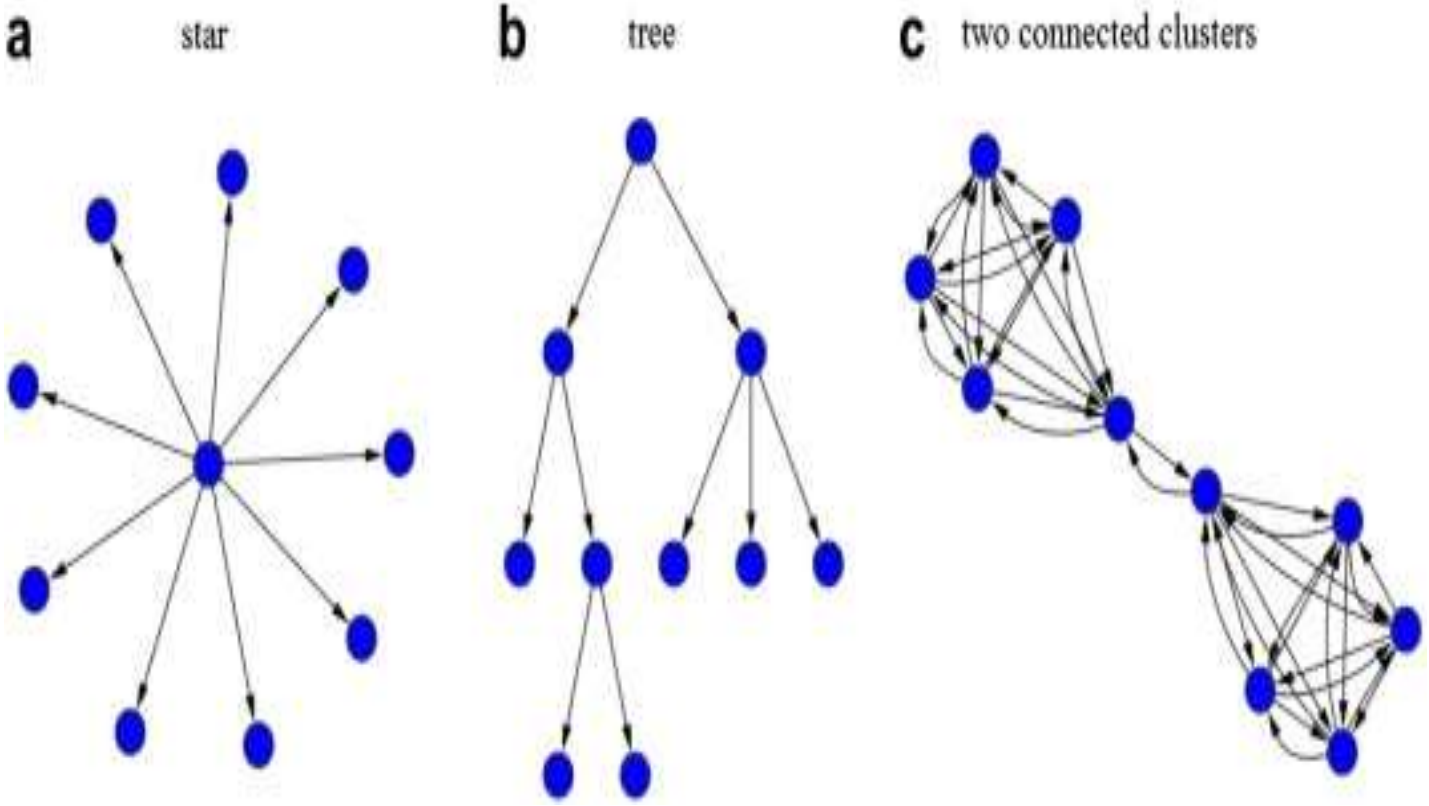
Degree centralization: number of individuals on which communication is based



High degrees of centralization of Perfusionist (P1) and Surgeon (S1) in transition from epoch 3 to 4

Time	Actor(s)	From actor	To actor	Notech observation	Category	Score	Epoch
10.17	S1-A1	S1	A1	How much is the ACT?	SA1	3	3
10.17	A1-S1	A1	S1	0	SA1	3	3
10.17	S1-A1	S1	A1	How do you know if the ACT is oke then? We will sum it up together later on	MS	5	3
10.19	P1-A1	P1	A1	ACT is 216	SA1	3	3
10.24	S1-P1	S1	P1	Can we start?	C	3	3
10.24	P1-S1	P1	S1	Just wait until the ACT is over 300	C	3	3
10.26	P1-S1	P1	S1	ACT is oke, you can start.	SA1	3	4
10.29	S1	S1	T1	Can you please talk a little louder today?	WM	3	4
10.30	S1-P1	S1	P1	Is the cardioplegie on the table yet?	C	3	4
10.30	P1-S1	P1	S1	Yes	C	3	4
10.32	S1-P1	S1	P1	How long is the plegie in this line already? (Just yet, so it's cold.)	SA1	3	4
10.32	P1-S1	P1	S1	Just yet, so it's cold.	SA1	3	4
10.34	P1-A1	P1	A1	Do you see a real flat ECG? (No, not yet)	SA1	5	4
10.34	A1-P1	A1	P1	No, not yet	SA1	5	4
10.37	P1-T1	P1	T1	Cardioplegie is stop	SA1	3	4
10.40	P1-S1	P1	S1	Blue stops sucking; can't be because he is running over here	SA1	3	4
10.49	S1-P1	S1	P1	Warm up the patient.	C	3	4
10.49	P1-S1	P1	S1	Ok	C	3	4
10.52	P1-T1	P1	T1	ACT is 771	SA1	3	4

Hierarchical (tree) versus non-hierarchical (star)

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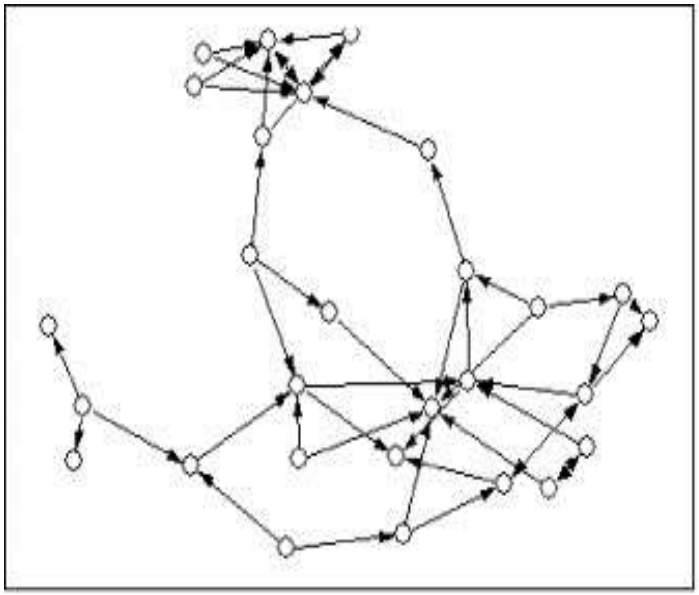
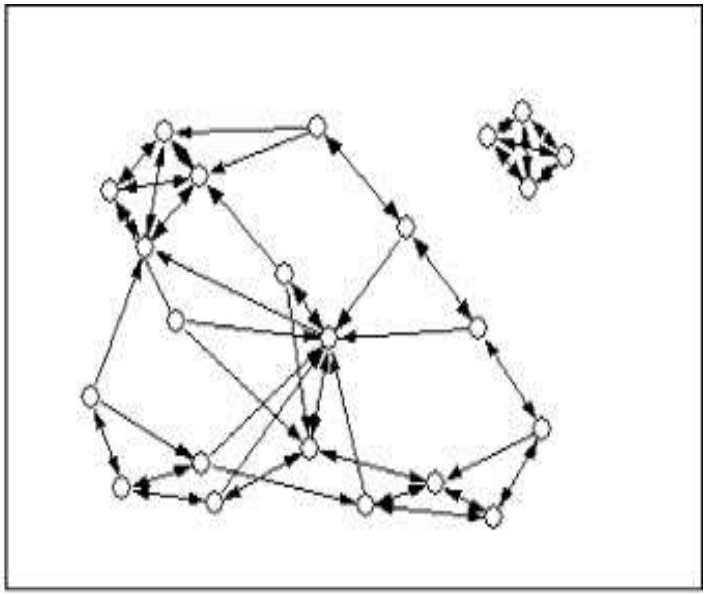
High degree of hierarchy (S1 in contact with many others); low degree of reciprocity

Time	Actor(s)	From actor	To actor	Notech observation	Category	Score	Epoch
08.43	A2-T1	A2	T1	ACT is running	MS	4	3
09.48	P1-T1	P1	T1	ACT is 350 and running	F	5	3
09.58	S1-P1	S1	P1	Please return all the blood you get. (Ok)	BB	4	4
09.58	P1-S1	P1	S1	Ok	BB	4	4
09.59	S1-P1	S1	P1	He drains very good.	Sa1	5	4
10.00	S1-P1	S1	P1	Plegie can be flushed	RA	5	4
10.00	S1-A1	S1	A1	The fontanel can be checked. No reaction	MS	3	4
10.07	A1-A2	A1	A2	Recalls A2, runs into the hallway to get A2 and tells her that the plegie isn't running	SA1	3	4
10.11	A2-T1	A2	T1	I am going to eat my cake in the hall	MS	5	4
10.12	P2-S1	P2	S1	Did you have any resistence with injecting by hand? (No)	SA1	3	4
10.12	S1-P2	S1	P1	No	SA1	3	4
10.14	P1-A1	P1	A1	A1 please kill the alarm	C	3	4
10.20	S1-P1	S1	P1	Much harder on blue, it doesn't suck oke.	SA1	3	4
10.21	P1-S1	P1	S1	Blue seems to suck stuck. (That true. Oke, just tell me so so I can do something about it)	SA1	4	4
10.21	S1-P1	S1	P1	That true.	SA1	4	4
10.21	P1-S1	P1	S1	Oke, just tell me so so I can do something about it	SA1	4	4
10.23	S1-N1	S1	N1	Is the gortex on the table? No. N2 gives it	MS	3	4
10.24	S1-N1	S1	N1	The gortex always can come on the table from the start when Fallots are concerned.	SA1	6	4
10.25	P1-T1	P1	T1	Regularly reports that blue doesn't suck well. No reaction by S-team	BB	6	4
10.26	S1-S2	S1	S2	Frequently gives S2 corrections because he doesn't handle the instruments the right way according to S1	C	3	4
10.32	S1-N1	S1	N1	Traction on this hand is supposed to be here (pulls on hand)	C	2	4
10.33	S1-P1	S1	P1	Blue suck stuck. If I put it on max. it will surely suck itself stuck.	SA1	3	4
10.34	P1-S1	P1	S1	Better this way? (If I don't respond it is oke, if you just tell me when it isn't (P1 shakes his head doubtfully))	MS	2	4
10.34	S1-P1	S1	P1	If I don't respond it is oke, if you just tell me when it isn't (P1 shakes his head doubtfully)	MS	2	4
11.03	S1-P1	S1	P1	How warm are you? (26. Start warming up till 30.)	C	3	4
11.03	P1-S1	P1	S1	26. Start warming up till 30.	C	3	4
11.03	S1-P1	S1	P1	We are ready with closing the VSD and we are going to check the ROVT and aortovalve now	Sa1	3	4
11.14	P2-T1	P2	T1	ACT is 463	RC	3	4

Reciprocity



Low reciprocity



High reciprocity

High degree of reciprocity (83% of the links reciprocal)

Time	Actor(s)	From Actor	To Actor	Notech observation	Category	Score	Epoch
10.10	A2-A1	A2	A1	ACT 418, do we need to give more?	SA1	3	3
10.10	A2-A1	A2	A1	I will give an additional amount of 400mg heparine	MS	5	3
10.10	P1-T1	P1	T1	ACT 400	SA1	3	3
10.13	A1-A2	A1	A2	A2 remarks that the patient maybe has not enough 'vulling' after defining the fact that the patient has a low ABP and high HF	D&D	4	3
10.13	A2-A1	A2	A1	A2 remarks that the patient maybe has not enough 'vulling' after defining the fact that the patient has a low ABP and high HF	D&D	4	3
10.16	S1-P1	S1	P1	Can we start?	C	3	4
10.16	P1-T1	P1	T1	60% flow	SA1	3	4
10.17	S1-P1	S1	P1	How much can you give?	SA1	3	4
10.17	P1-S1	P1	S1	60%	SA1	3	4
10.20	S1-A1	S1	A1	Is the fibrillator turned on? (No, puts it on)	SA1	2	4
10.20	A1-S1	A1	S1	No, puts it on	SA1	2	4
10.21	P1-S1	P1	S1	Temperature 34º? (No, leave it like this)	MS	3	4
10.21	S1-P1	S1	P1	No, leave it like this	MS	3	4
10.24	N1-N2	N1	N2	With which scissor is he going to cut the patch? This one? (Yes)	C	3	4
10.24	N2-N1	N2	N1	Yes	C	3	4
10.26	S1-N1	S1	N1	What kind of needle is this?	SA1	3	4
10.26	N1-S1	N1	S1	Profileen	SA1	3	4

Time	Actor(s)	From actor	To actor	Notech observation	Category	Score	Epoch
12.50	S1-P1	S1	P1	Where are you now? (35 degrees)	SA1	3	4
12.50	P1-S1	P1	S1	35 degrees	SA1	3	4
12.50	S1-P1	S1	P1	Okay we are ready.	SA1	3	4
12.50	S1-A1	S1	A1	Can we come of HLM? (No we wait until we are some over 35.)	MS	4	4
12.50	A1-S1	A1	S1	No we wait until we are some over 35.	MS	4	4
12.52	S1-A1	S1	A1	Now?	SA1	3	4
12.52	A1-S1	A1	S1	Yes	C	3	4
12.53	A1-T1	A1	T1	HLM is stopped.	SA1	3	5
12.53	P1-S1	P1	S1	Lessen input? (Yes if you can stop filling.)	MS	3	5
12.53	S1-P1	S1	P1	Yes if you can stop filling.	MS	3	5
13.02	A1-P1	A1	P1	Protamine is in.	SA1	3	5
13.05	A3-S1	A3	S1	Arterial line is gone for a while	SA1	4	5

ORA User's Guide 2012

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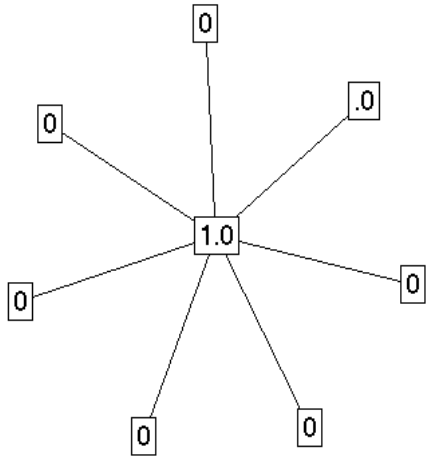
Center for the Computational Analysis of Social and Organization Systems
CASOS technical report

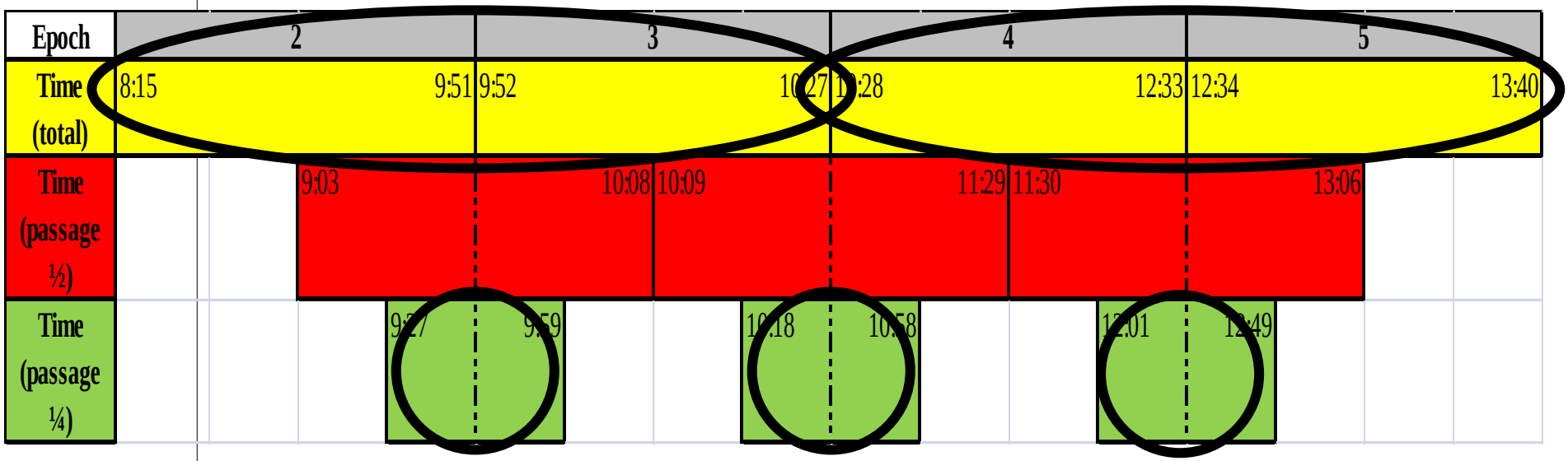


Results

TNO innovation for life

During transitions:

* communication is based on fewer individuals
* information flow is faster



Differences between epochs

- CPB preparation (from epoch 2 to 3)
  - More connections to other highly-connected team members
- Going on CPB (from epoch 3 to 4):
  - Communication more based on a few individuals closer to transition
  - More connections to other highly-connected team members
  - More hierarchical communication patterns
- Going off CPB (from epoch 4 to 5)
  - Fewer hierarchical communication patterns
  - Denser networks

Results on complexity of procedures (median split)

More complex procedures:

- Have flatter communication structures, are less hierarchical
- Show higher levels of reciprocity

How do team members respond to NREs?

- Generally, NREs are responded to by lowering the centrality of the main actors, that is, the team as a whole becomes more dominant in comparison to single actors (surgeon, anaesthetist)
- However, only during the most critical phases of the most complex procedures, do single actors become more dominant as the number of NREs increases

Conclusions

- Teams adapt their communication patterns to:
  - Complexity of the procedure
  - Transitions between epochs
  - Criticality of epochs
  - Non-routine events

- Complexity and non-routine events are responded to with a **broadening** of communications, higher reciprocity and denser networks
- Transitions during critical epochs are responded to with **restricting** communication to key individuals


What makes for an excellent OR team?

- Being able to flexibly adapt communication patterns as the situation demands
  - Not sticking rigidly to hierarchical communication, but involving the team as a whole in case of non-routine events and complex (parts of) procedures
- Heedful interrelating: being attentive to each other's needs
  - Stable patterns of interaction lead to uninterrupted surgical flow

Turning a team of experts into an expert team requires a process of heedful interrelating

Heedful interrelating

Recommendations

- Team research should move beyond general labels such as ‘leadership’ and ‘situation awareness’ and instead focus on adaptive team processes in context
- Social network analysis is able to characterize team processes at a fine-grained level
- This provides a solid basis for improving team communication processes and, ultimately, clinical performance

TNO innovation for life

Thank you!