Assessing Performance and Human Factors in Paediatric Cardiac Surgery

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Safety in National Systems

12,649 NRLS incidents associated with anaesthesia Jan 2004 – Feb 2006

“...none of the reviewers have ever filled in such a report, or knew of anyone who had.”

Safety at the “Coal Face”

Initiation of bypass without sufficient heparin is catastrophic

Hospital A
- Surgeon: Heparin please
- Anaesthetist: Okay, heparin
- Anaesthetist: Heparin going in
- Surgeon: Are we ready to go on bypass?
- Anaesthetist: Yes, ready
- Perfusionist: Yes, I’m ready

No recent heparin incidents

Hospital B:
- Surgeon: Okay?
- Anaesthetist: Yes
- Surgeon: Alright then

“It’s fine if you know how we do it here.”

“About 6 months ago when we had a bit of an incident with someone new, but they weren’t here long.”
System Threats
Organisation
Environment
Task
Patient

Major Problem

Human Errors
Technical
Non-Technical

Minor Problem

Major Problem

Adverse Event
What did we do?

- Two surgical environments
  - Paediatric cardiac surgery  24 cases
  - Orthopaedic surgery       20 cases

- In-theatre observations made in real-time

- Video recording made of each operation

Measures

- Minor failures – *small process problems*
- Major failures – *events that came close to accidents*
- Non-technical skills – *cognitive and team-working skills*
Decision-related surgical error

Known problem

Fatigue

External pressures

Psychomotor-related perfusion error

Resource management

Fault resolution

Psychomotor Error (general)

Pre-operative diagnosis failure

Temperature control difficulties

Planning failure

Perfusion difficulties: technical

Team Conflict

Perfusion difficulties

Expertise / skill failure

Procedure-related Error

Vigilance / awareness

Equipment / Workspace management

Distraction

Equipment failure

Patient-sourced procedural difficulties

Safety consciousness

Unintended effects on patient

Equipment Configuration failure

Co-ordination / communication

Absence

Minor Problem Types

24 Operations

366 minor problems

29 different types

PAEDIATRIC CARDIAC SURGERY

1.1 First Incision
1.2 Exposure of treatment area
1.3 Anatomical inspection
1.4 Heparin is administered
1.5 Cannulation
1.6 Bypass is initiated.

2.1 Surgical Tasks
2.2 Maintenance of effective perfusion
2.3 Temperature control
2.4 Cross-clamp protocols
2.5 Cardioplegia administration
2.6 DHCA Requirements
2.7 Weaning from bypass

3.1 Ultrafiltration
3.2 Stabilise patient
3.3 Assess treatment
3.4 Decannulation
3.5 Heparin reversal
3.6 Closure

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Pediatric cardiac surgery

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Access
Treatment
Closure

Number of Minor Problems

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Sources of Minor Failure

**THREATS**
- No Threat (Error only), 76, 21%
- Cultural / Organisational, 85, 23%
- Environmental and Cultural / Organisational, 12, 3%
- Environmental, 54, 15%
- Task and Environmental, 19, 5%
- Task, 33, 9%
- Patient and Task, 87, 24%

**ERRORS**
- Technical Errors, 67, 18%
- No Error (Threat Only), 174, 48%
- Technical and Non-Technical Errors, 25, 7%
- Non-Technical Errors, 100, 27%

**Citation**
Operations by Risk Level

Minor Failures Per Operation (Paediatric Cardiac Surgery)

"Low" Risk Operations

"High" Risk Operations

Significant difference between failures in “low” and “high” \([u = 29.5, p<0.05]\)
Operations by Risk Level

Minor Failures Per Operation (Paediatric Cardiac Surgery)

<table>
<thead>
<tr>
<th>Minor Failures Observed</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
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<th>Level 6</th>
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<tbody>
<tr>
<td>&quot;Low&quot; Risk Operations</td>
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Major Failures
Major Failures

- **Paediatric Cardiac**
  - Swab causes compression of right coronary artery
  - Ex-sanguination during post-bypass haemofiltering
  - Omission of key surgical step
  - Premature separation from bypass due to breakdown in teamwork
  - Aortic homograft ruptured during sternotomy
  - Incorrectly labeled homograft
  - Difficult management of activated clotting time

- **Orthopaedics**
  - Multiple uncertainty leads to teamwork and task breakdown.

Examples of minor failures implicated in major failure sequences:
- **Communication/co-ordination** failures in 5 out of 8 major failures
- **Absences** in 4 out of 8 major failures
- **Equipment failures** in 4 out of 8 major failures
- **Vigilance/awareness failures** in 3 out of 8 major failures
Ex-sanguination fortuitously mitigated

Context
– 3hrs 46minutes into a Norwood stage-1 operation
– reasonably event-free surgical progress
– just come off bypass with low oxygen saturations (approx 70%)
The Build-Up

13:22 S: Are you happy or not? AC: yes, I’m happy
13:33 S: where is arterial line? AC: femoral
13:34 AC operates anaesthetic workstation. S: You’re not giving. P: Should be improved. AC: we changed the scale.
13:35 Discussion of desired haematocrit levels
13:36 AC (to perf): don’t let the green RAP go too high. Probably want it at 14.

6 different types of equipment
Equipment / team / process coupling
The Event

13:39 P: Filtration stopped. AC: What’s the crit? P: 40. AC (to P): I think we ought to continue + discussion of new plan. Meanwhile, surgeon takes the MUF line out. 1A is involved in planning, but thinks the agreement is to concentrate the blood in the pump.

13:40 1A: got a gas? AC: reads out bloodgas

13:41 Surgeon asks for more calcium.


13:43 P & AC make new filtering plan.

New plan not clearly communicated

Task conflict; attention elsewhere

Fortuitous co-ordination

Early Mitigation

New plan co-ordinated

Error goes unnoticed for >120s
Major Failure 2: Surgical Omission

CONTEXT
- Trainee perfusionist overseen by senior perfusionist
- Light handle cover omitted
- Infusion pumps not plugged in until 80 mins after 1st incision
- Anaesthetic consultant periodically absent, leading to:
  - Inappropriate support to registrar
  - 11:54-12:31 Poor starting and heparin communication protocols
  - 12:36 Registrar can't operate ACT machine properly (thinks it is broken), leading to 3 minute delay in obtaining ACT

- 12:54 Undiagnosed intramural coronary pattern found
- 13:23 Perfusion air lock
  - Sucking on red vent allows air to travels across septal defect; surgical field fills up; Senior perfusionist sorts out problem
The Event

- 14:27 Rewarming starts
- 14:31 Surgeon finishes construction of the neo-aorta. x clamp is removed unannounced.
- 14:34 External registrar talks to surgeon about the case
- 14:36 Anaesthetic consultant returns after absence.
- 14:37 Heart begins to beat
- 14:38 Surgeon realises he’s forgotten to close the septostomy.
- 14:39 Rewarm halted
- 14:40 Venous return re-configured
- 14:48 Septostomy closed

Violation of normal procedure
Distraction
Unaware septostomy is not closed
Error identified
Mitigation Plan
Major Failure 3: Compression of Coronary Artery in ASO

CONTEXT (POST BYPASS)
- LeCompte manoeuvre fails due to patient anatomy, requiring alternative strategy
  - MPA transected at bifurcation
- Continued post-bypass bleeding due to surgery
  - Compounded by lack of blood products
  - Sub-optimal ACT protocols
    - Missed communications between AC & perfusionist mean sample is left in uncovered syringe for 3 minutes before being placed in machine
- Lungs wet post-bypass
  - AC balances SATs & lung stiffness by alternating between automatic & bag ventilation
- Difficulty visualising repair with echocardiogram
  - ToE not possible; control of ventilation is difficult
- Temperature overshoot
- Next patient is pre-medded, then has to be re-scheduled
  - Anaesthetist asks ward to pre-med the next patient before bleeding is apparent
- Frequent changes in surgeons at the table
  - 1st Assistant surgeon leaves table at 13:33 & returns at 14:09
  - Consultant Surgeon leaves table at 14:06 & returns at 15:07
  - 2nd Assistant Surgeon leaves table at 14:35 & returns at 14:49
The Events

14:00-15:00 Considerable number of swabs/clotting aids used

15:03 Heart has swelled and is beginning to look very purple. SATS at 78; ETCO at 3.9
- 1A discusses hypoxia
- S (not scrubbed): maybe we should check another echo
- 1A: that's happened in the last 3 or so minutes
- S: lost sinus rhythm as well.

15:04 S: back in sinus rhythm. What's happening?
- 1A: the right ventricle isn't moving
- S: what's happening?
- S goes to scrub up again.
- AC: we need some pacing. Pacing box is connected

15:05 AC: Atrial flutter. Let's try a trans-atrial shock
- 1A: Okay, let's try to defibrilate
- AC prepares the de-fib;
- 1A reaches for the paddles; the headlight generator is in the way, and there is a sheet covering the paddles. 1A: "Is that clean?" SN nods.
- Heart is shocked

15:06 1A inspects surgical site
- S: there's got to be a reason for it. We've got to find out.
- AC: Has somebody called for an echo? Will somebody call?. The runner goes.

15:07 1A still inspecting surgical sites
- S arrives at table - takes the 1A position

15:07 - 15:10 1A and AC in diagnostic discussions & measurements
The Events

- **15:11 AC**: if we get the sats up, everything will be better.
  - **1A**: ETCO's way off
  - **AC**: now blood flow
  - **S**: we’ve had no problems with the right coronary
  - **1A**: I put a stitch on the <unintelligible>
  - **S**: that could be it.

- **15:12** **1A & S** discuss possibility that it's 1A's stitch
  - **Echo machine arrives**
  - **1A investigates area of R coronary with suction**
  - **AC**: have you got some heparin ready? (To AR): can you get some heparin ready?

- **15:12** **S** removes small section of mastoid strip from area of R coronary
  - **Sats & ETCO rise**
  - **AC**: that looks better

- **15:13** Realisation & relief

- **15:20** Discussion of the error

- **Diagnosis moving closer**

- **Fails to see problem again**

- **Problem identified**

- **Confirms the solution**

- **Review events but not how it could have been avoided**
Teamwork in the Cardiac Operating Theatre
# Surgical NOTECHS

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Elements</th>
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| Leadership & Management          | Leadership  
Maintenance of Standards  
Planning & Preparation  
Workload Management  
Authority & Assertiveness       |
| Teamwork & Co-operation          | Team building & Maintaining  
Support of others  
Understanding team needs  
Conflict solving              |
| Problem Solving & Decision Making | Definition & Diagnosis  
Option Generation  
Risk Assessment  
Outcome Review               |
| Situation Awareness              | Notice  
Understand  
Think Ahead                |

<table>
<thead>
<tr>
<th>Below Standard (1)</th>
<th>Basic Standard (2)</th>
<th>Standard (3)</th>
<th>Exceed (4)</th>
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Failures and Non-Technical Skills (Paediatric Cardiac Surgery)

Spearman’s Rho = 0.738, n=24, p<0.001
Non-technical Errors

**Leadership & Management**
- Leadership
- Maintenance of Standards
- Planning and Preparation
- Workload Management
- Authority & Assertiveness

**Teamwork & Co-ordination**
- Team building & maintaining
- Support of others
- Understanding team needs
- Conflict solving

**Problem Solving & Decision Making**
- Problem definition & diagnosis
- Option Generation
- Risk assessment & option selection
- Outcome Review

**Situation Awareness**
- Noticing
- Understanding
- Thinking Ahead

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Total Number of Observations

- Paediatric Cardiac Surgery
- Orthopaedic Surgery