UNIVERSITY OF ROCHESTER MEDICAL CENTER

UNIVERSITY OF ROCHESTER EMERGENCY MEDICINE Est. 1994

Human Factors Engineering

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Overview

- Case study presentation
- Human error
- Systems approach
- Human Factors Engineering (HFE)
- Examples inside and outside medicine
- What you can do now

Case Study

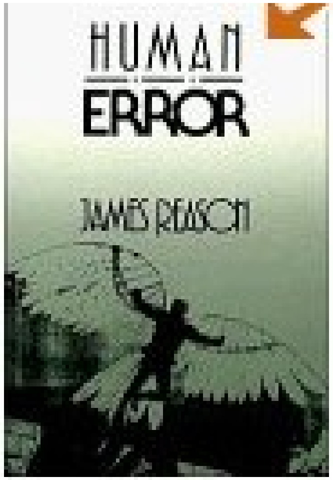
- 32 year old healthy male
- Presents to ED
  - chest pain, low BP, rapid heartbeat
- Cardioversion @50j → refractory
- Repeat cardioversion @ 100j → VF arrest
- 45 minute resuscitation→ patient dies
- Code summary revealed that nurse failed to put device in SYNC mode for second shock

Case Study

- Response?
  - Fire the nurse?
  - Retrain the ED staff?
  - Forbid nurses from defibrillating?
  - New policy? Memo?
- Root cause analysis:
  - Human error?
  - Inadequate Training?
  - Familiarity with device?

What is Human Error?

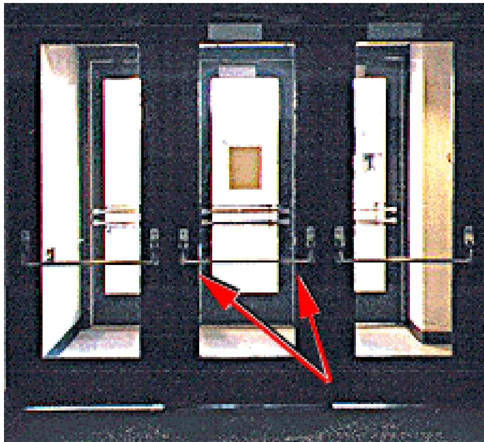
- Definition (Reason, 1990)
  - “The failure of a planned action to be completed as intended” (error of execution)
  - “the use of a wrong plan to achieve an aim” (error of planning)
- “Plan the flight and fly the plan”
- Human Error: Big consequences
  - Three mile island
  - Challenger
  - Chernobyl



Types of Human Error

- Active Errors: effects felt immediately
  - Front-line operators (pilot, ATC, RN, MD)
- Latent Errors: adverse consequences lie dormant within system
  - Designers, high-level decision makers, construction workers, managers, maintenance personnel

J. Reason, Human Error, 1990



Human Error

Goal: "Eliminate Medical Error?"

NO!!!

- Human Error cannot be eliminated
- Futile goal; misdirects resources
- Causes culture of blame and secrecy
  - "name, blame, and train" mentality
- It is about HARM, not ERROR

Typical Human Error Rates

0.003	Error of commission, e.g. misread label
0.01	Error of omission without reminders
0.03	Simple arithmetic errors
0.10	Inspector fails to recognize error
0.25	very high stress/dangerous activities/rapid

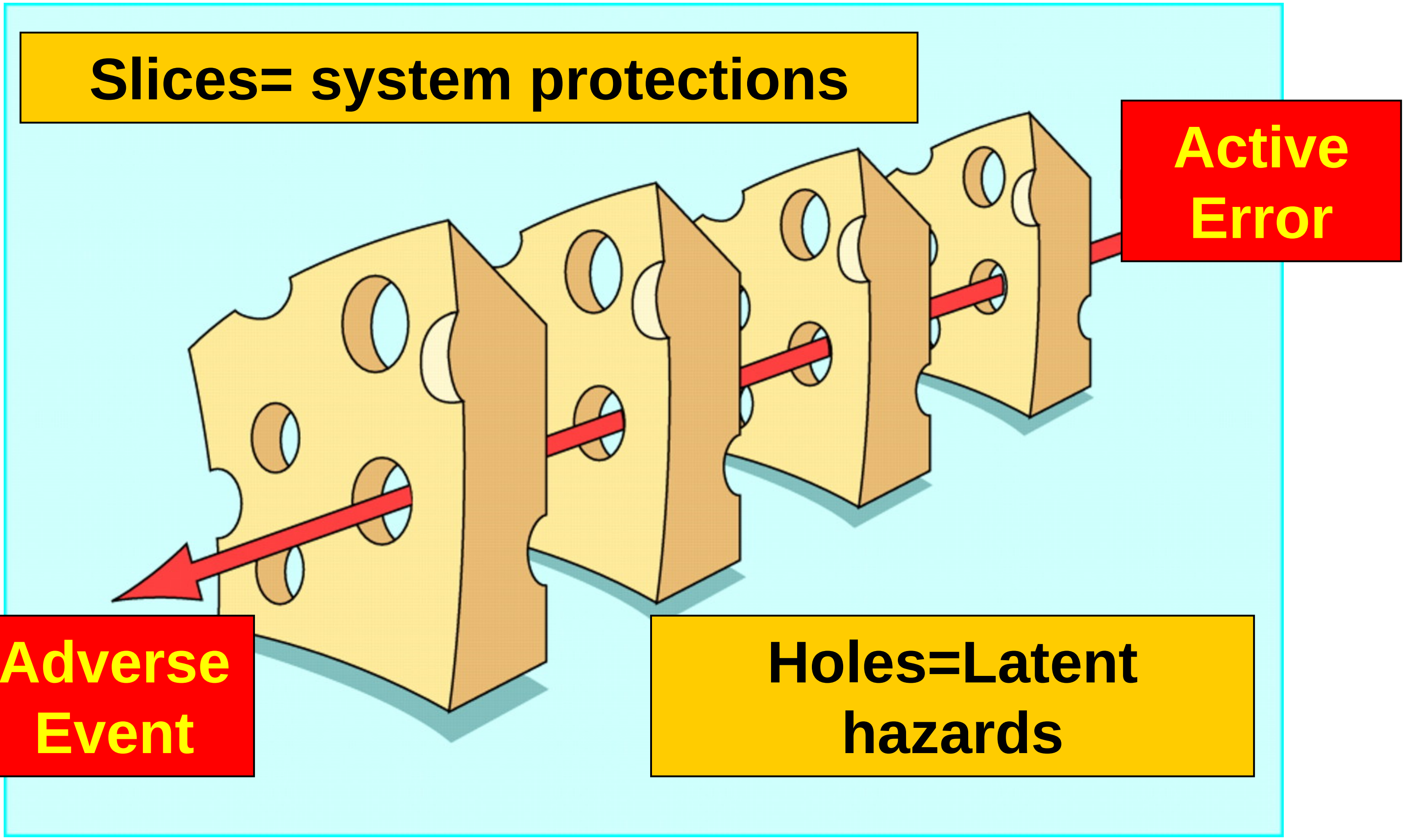
From Park K. Human Error, in Salveny G, ed.. Handbook of human factors and ergonomics

- To become a high reliability organization, cannot depend on the human component
  - Wire case...

Mitigating Human Error

- If error is inevitable... How to improve safety?
  - Reduce the occurrence of human error
  - Mitigate the effects of inevitable error
- System design
  - “Error trapping”
  - “Mistake mitigation”

Swiss Cheese Model (Reason)

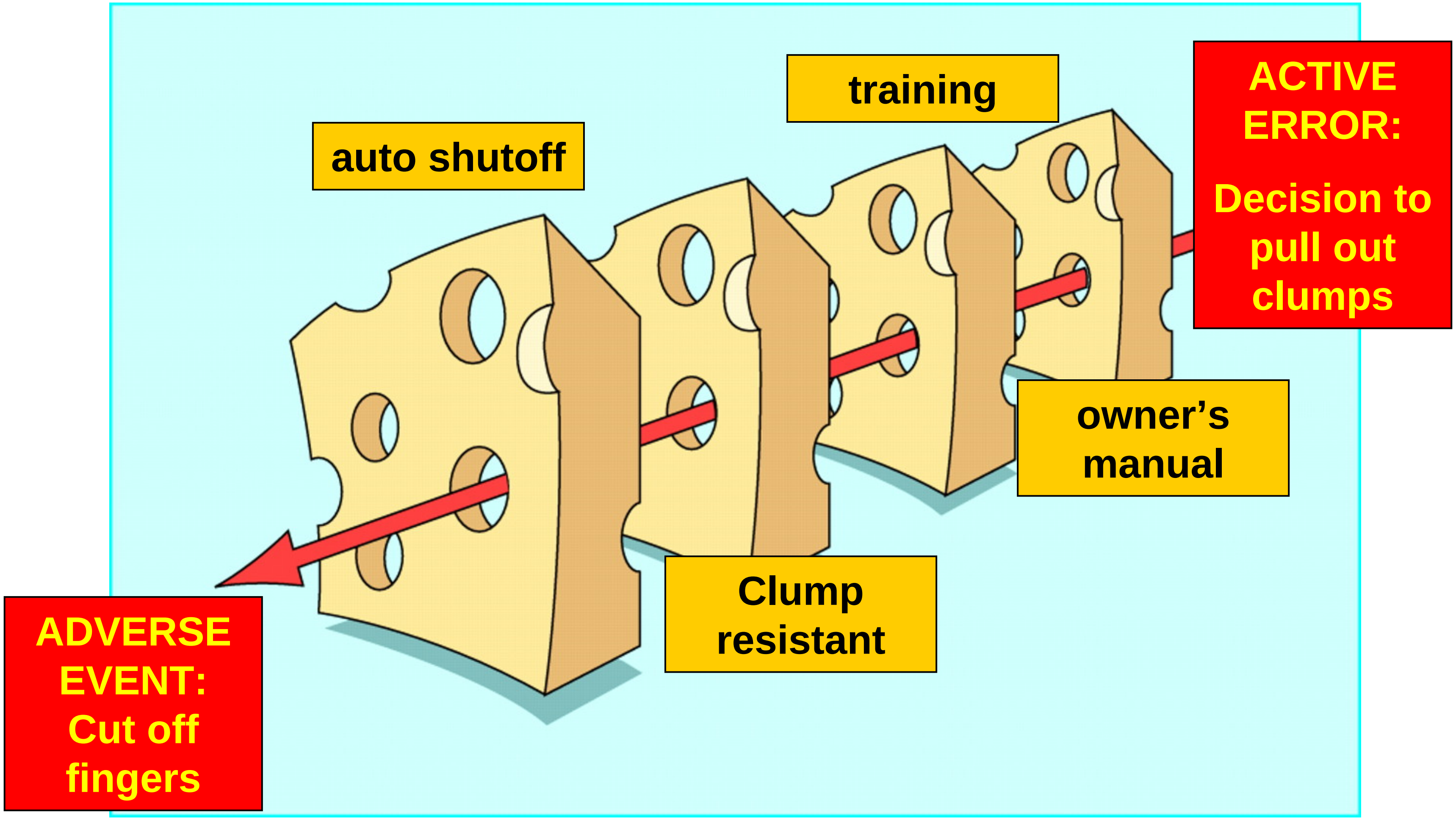


Modified from Reason, 1990

Lawnmower: System Protections

- Old protections
  - User manual
  - Training at sale
- New Design Features
  - Clump resistant
  - Blade not within reach
  - Forcing Function: Auto shutoff

Lawnmower Swiss Cheese



Modified from Reason, 1990

Culture→ Realities

"Most serious medical errors are committed by competent, caring people doing what other competent, caring people would do."

-Donald M. Berwick, MD, MPP

- Not just about the people
- About the design
  - System, medical devices, procedures

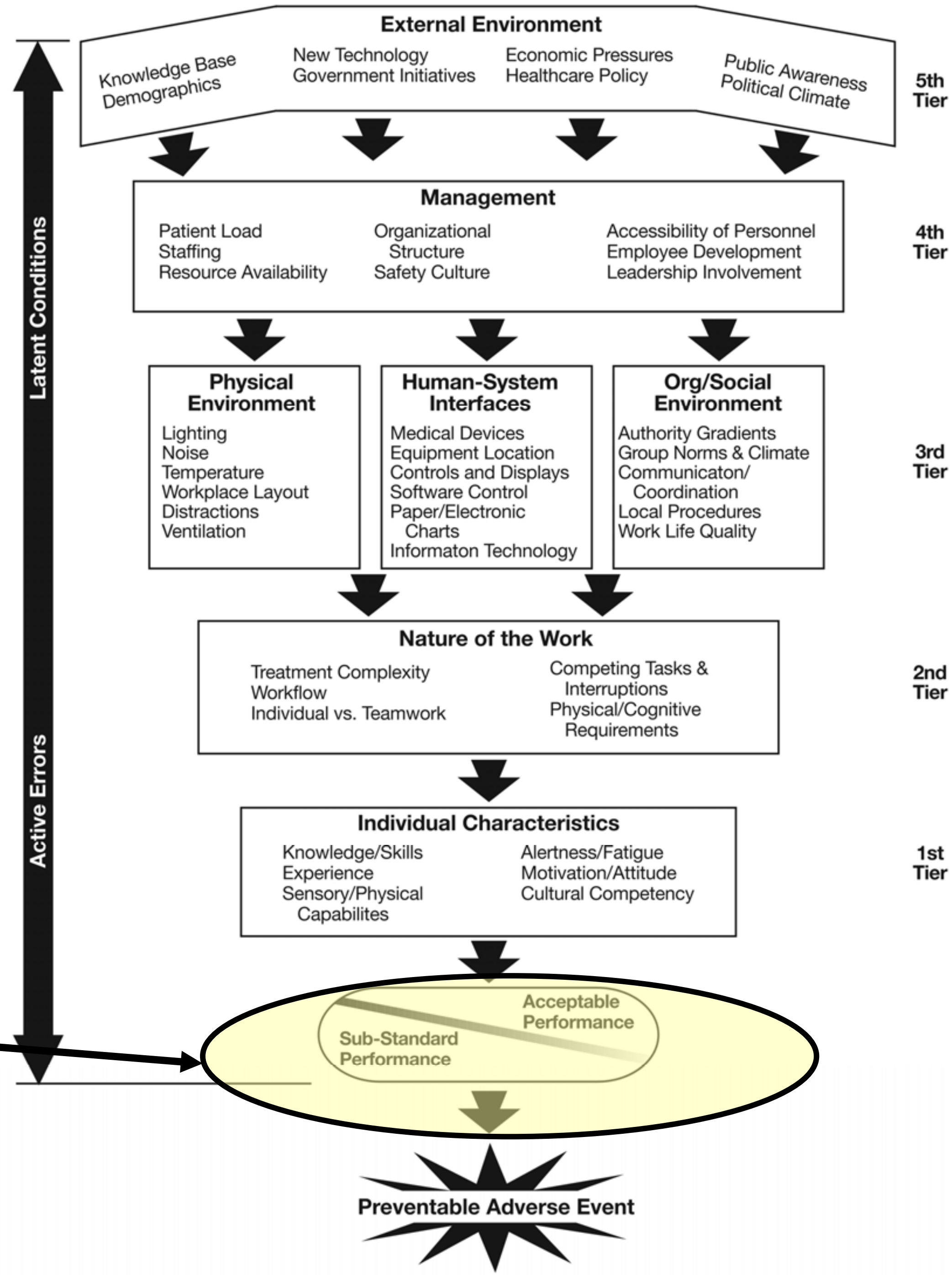
Culture→ MYTHS

- It is BAD to make a mistake ("Who is at fault?")
- Human error is preventable through:
  - Training
  - Remediation
  - Guidelines
  - Protocols
  - Fear of discipline
- The systems approach protects "bad providers"

Contributing factors to adverse events in health care.

Diagram credit:
Kerm Henriksen, PhD (AHRQ)

Sometimes hard to distinguish



System Design

- After errors are identified, systems can be designed to compensate for the error
  - "Keep the error from reaching the patient."

"Every system is perfectly designed to achieve exactly the results it gets"

--Donald Berwick, MD (1999)

Defibrillator Case: Contributing Factors

- Design issues
  - Lack of user feedback
    - Device silently leaves sync mode
  - Lack of forcing function
    - Allows unsynchronized shock for SVT
- Standardization issues
  - Hospital has several different makes
- Liability issues, culture of blame
  - Prior cases known, others not

Defibrillator Usability Study

- Fourteen paramedic participants
- Four tasks: 2 routine, 2 emergent
- Two defibrillator models
- SimMan™ patient simulator
- 50% of participants inadvertently delivered an unsynchronized countershock for SVT
  - 71% of participants never aware

➢Fairbanks RJ, Caplan S, et al. *Defibrillator Usability Study Among Paramedics, Proceedings of the Human Factors and Ergonomics Society Meeting. www.HFES.org, 2004*

➢Fairbanks RJ, Caplan SH, et al. *Usability Study of Two Common Defibrillators Reveals Hazards. Annals of Emergency Medicine, epub ahead of print, DOI: 1016/j.annemergmed2007.03.029, 2007 (in press)*

Response

- Fire the nurse?
  - Creates culture with incentive to hide errors
  - Results in less experienced workforce
- Retrain the ED staff?
  - Ineffective way to improve system reliability
- Study past events?
  - Requires culture change
  - True protected reporting
- Improve medical devices interface design?

Defibrillator design

- AED inadvertent actuation
  - Power button when shock intended
- Monitor/Defibrillators
  - SYNC issue
  - Ability to power down during pacing mode
- Why is this all possible???
  - Culture in medicine:
    - The provider should know how to operate device
    - “device functioned as intended”

Human Factors Engineering

- Human Factors Engineering tries to:
  - Optimize the relationship between technology and the human user
  - Design the system to match abilities
- Designing for human use
- Prominent in aviation, nuclear, automotive, military, system safety engineering

Human Factors: Definition

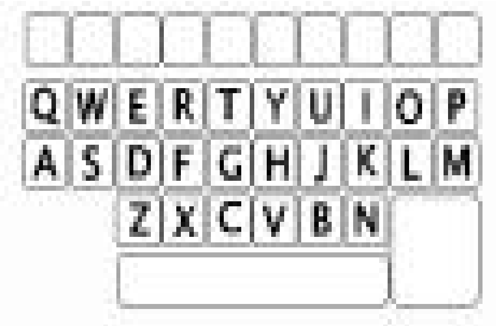
"Human factors applies knowledge about human strengths and limitations in the design of interactive systems of people, equipment, and environments to ensure their effectiveness, safety, and ease of use."

- How humans err is not the focus
- Focus on the interaction or interface between people and the system (tools, devices, environment).
- Fit the tools and environment to the person; not the person to the tools and environment (training)
- Put knowledge in the system rather than knowledge in the head (forcing functions)

--Adapted from Kerm Henriksen PhD, AHRQ

System design

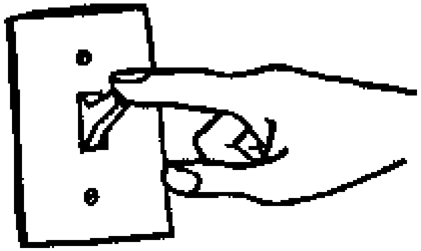
- The QWERTY keyboard



System Design

- Population Stereotypes

OFF or ON?



- On/off switch
- Faucets
- Screws
- Volume control

System Design

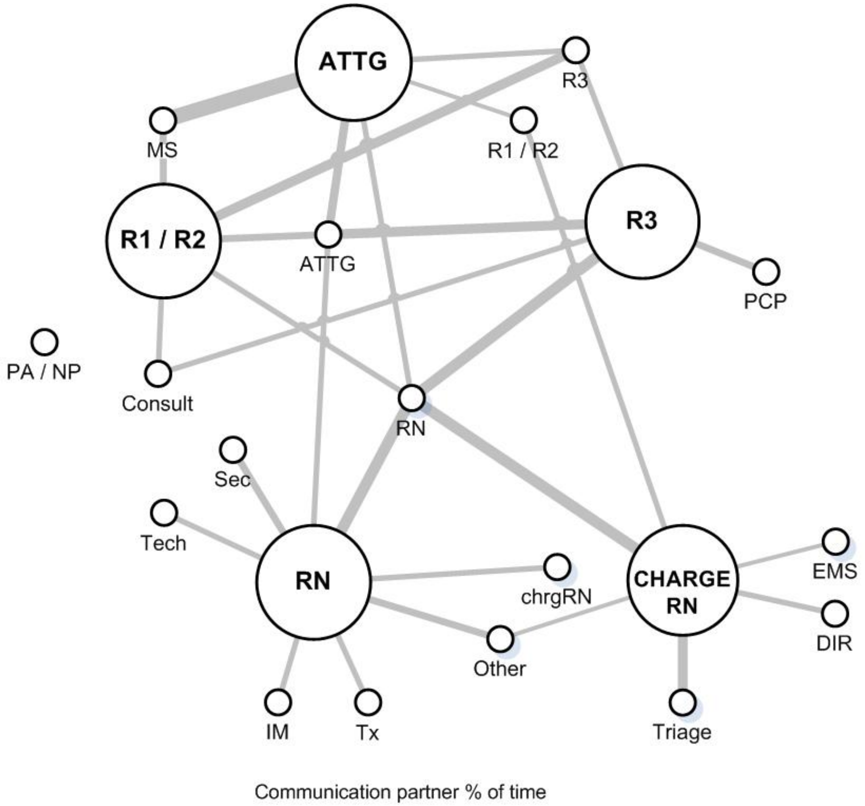
- Minimize opportunity for errors

From S. Caplan, © 2003 Usability Associates

Latent Error in the ED

- Communication
- Situational awareness is critical
- Study of 5 EDs:
  - Nurses and Doctors never signed out together

    (Wears and Perry)



Fairbanks RJ, Bisantz AM, Sumn M. Emergency Department Communication Links and Patterns. Annals of Emergency Medicine (in press).

Test	Result	Flag	Date	Time	27	28	29	30	31
IRON	42	L							
TIBC	267								
TRANSFERRIN SAT	16	L							
FERRITIN	101								
CL	108								
CO2	23								
K	3.3	L							
NA	139								
UN	38	H							
CREAT	5.4	H							
GLU	85								
CA	8.2	L							
PHOS	2.5								
MG	1.6								
TP	7.3								
ALB	3.9								
TB	1.2								
D BILI	< 0.1								
AST	30								
Test	Result	Flag	Date	Time	Su	Mo	Tu	We	Th

Instinx by THE SHAMS GROUP Inc. (TSG)

File Edit Configuration Connect Help

128.151.22.1 | Capture Off | Telnet connection success

Toolbar

Home Yes No Esc EXIT OK

Pt [redacted] Unit # 0000370053 Age/Sex 51 M User ED.TRF

DIS - 05/07/03 UNK REG ER - Aug 11, 2003

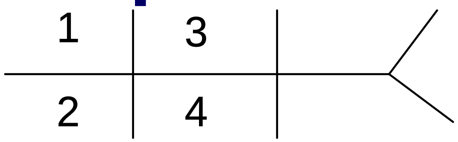
Laboratory Data Summary Mon - Aug 11 (14:59)

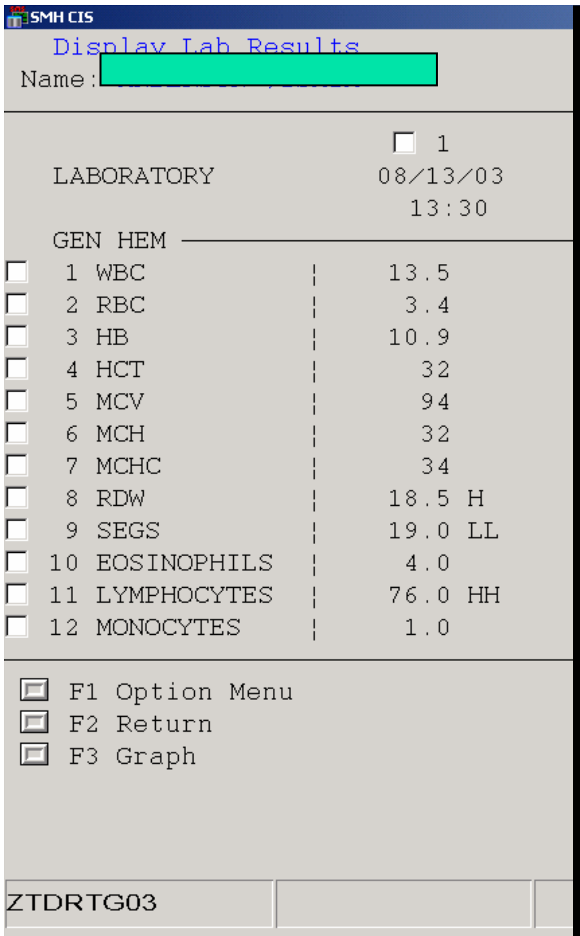
Print Split Time Highlights Jump

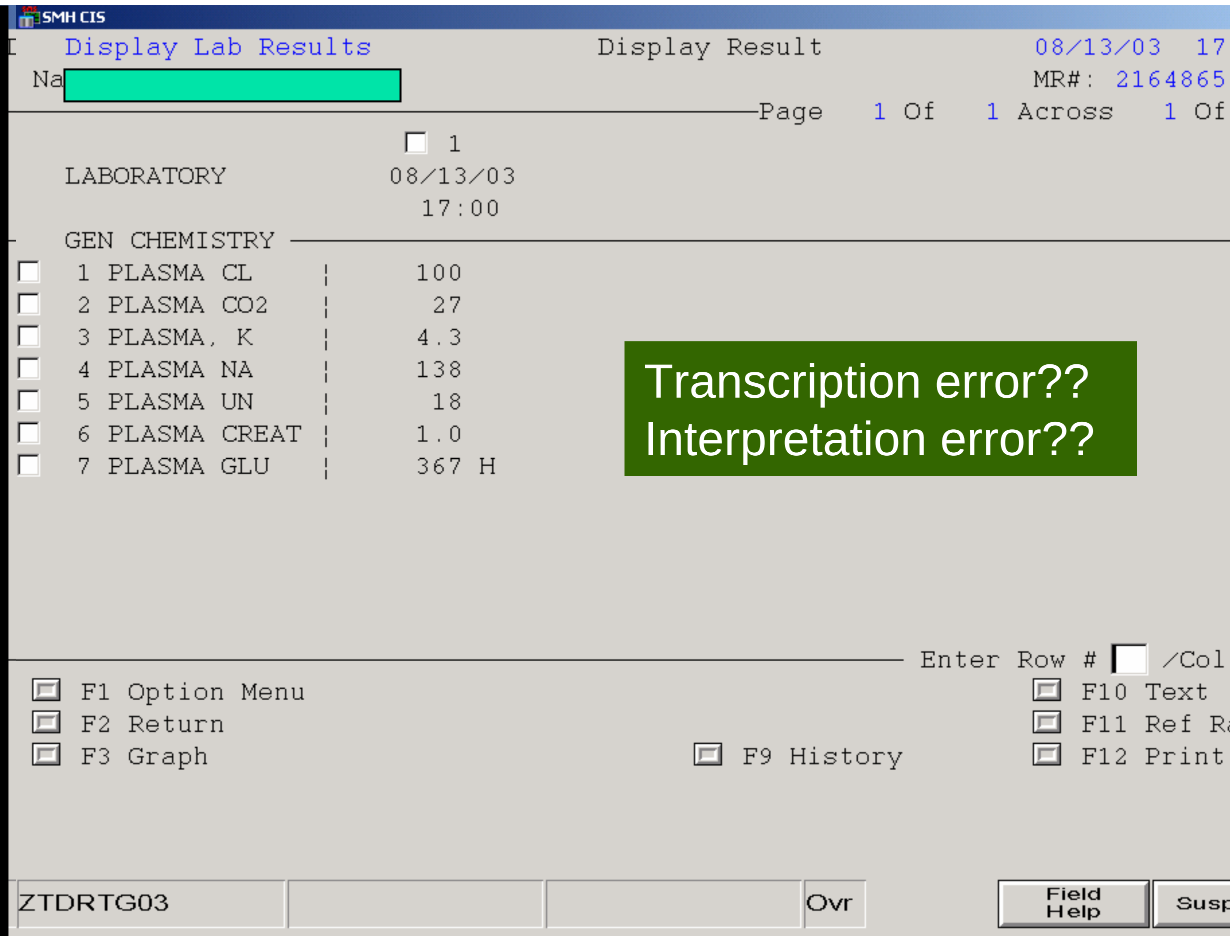
16 Days ← Aug 11, 03

Test	Result	Flag	Date	Time	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11
IRON	42	L	(May 07, 03)																	
TIBC	267		(May 07, 03)																	
TRANSFERRIN SAT	16	L	(May 07, 03)																	
FERRITIN	101		(May 07, 03)																	
CL	108		(May 07, 03)																	
CO2	23		(May 07, 03)																	
K	3.3	L	(May 07, 03)																	
NA	139		(May 07, 03)																	
UN	38	H	(May 07, 03)																	
CREAT	5.4	H	(May 07, 03)																	
GLU	85		(May 07, 03)																	
CA	8.2	L	(May 07, 03)																	
PHOS	2.5		(May 06, 03)																	
MG	1.6		(May 07, 03)																	
TP	7.3		Aug 11	12:41																7.3
ALB	3.9		Aug 11	12:41																3.9
TB	1.2		Aug 11	12:41																1.2
D BILI	< 0.1		Aug 11	12:41																< 0.1
AST	30		Aug 11	12:41																30
Test	Result	Flag	Date	Time	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo

Examples of Simple HFE Problems







Transcription error??
Interpretation error??

Visual Display
Pyxis Machine- all caps?

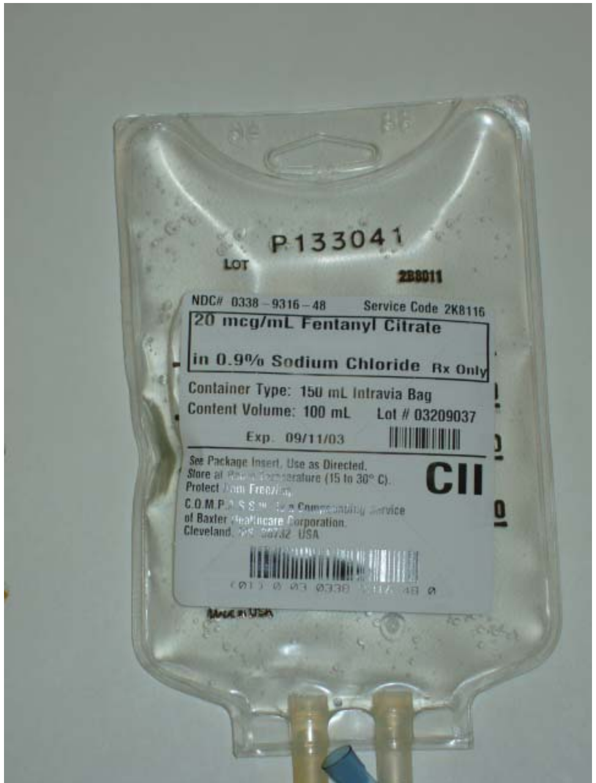
CABINET   SPEAKER

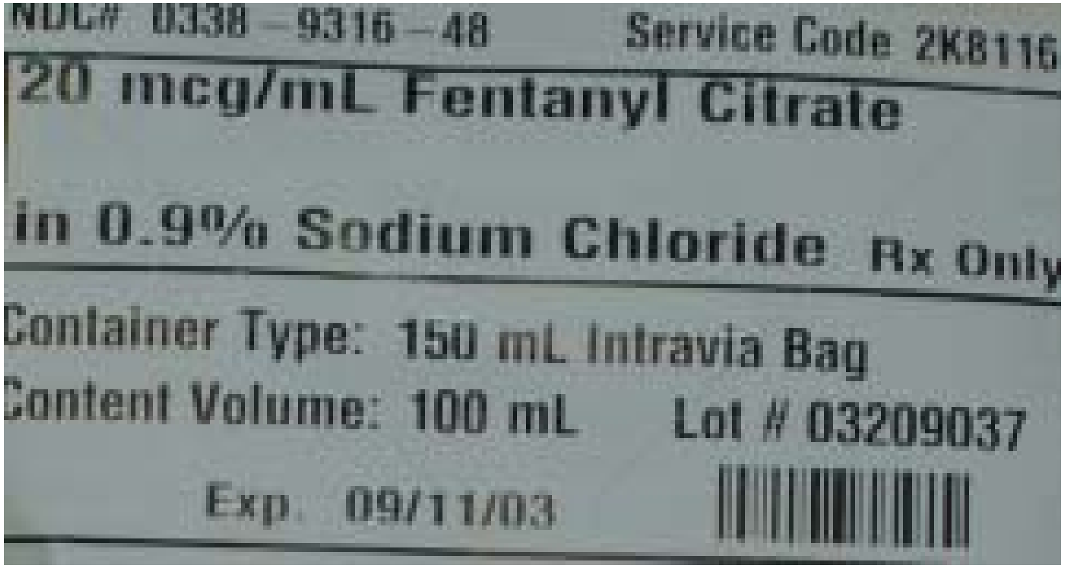
cabinet   speaker

From: Stan Caplan, Usability Associates

Can Pyxis Facilitate Error?

20 mcg Fentanyl IV Push Please!



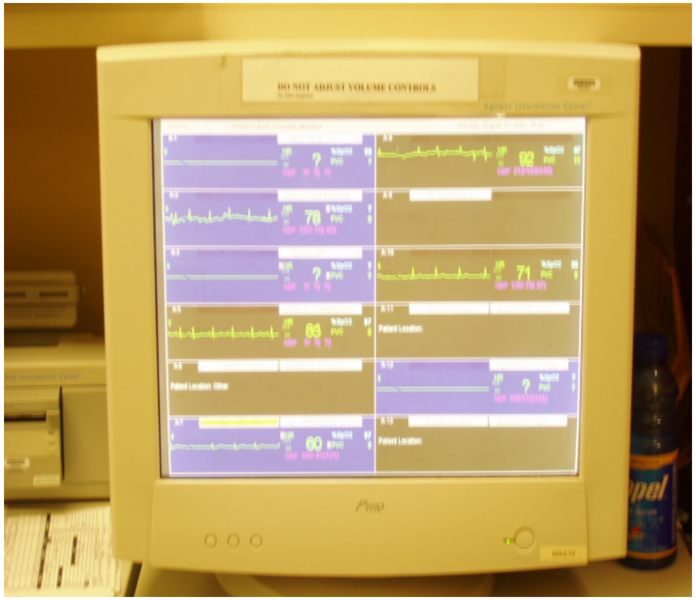


Case

- 74 year old woman to ED for syncope
- Monitored in ED
- Workup negative
- Admitted, but hospital full
- Inpatient orders written (boarding)
- On bedside monitor & telemetry
- 3:30am- blood drawn
- 5:30am....

The monitor case

- Hospital response
  - Lock out HR alarm override
  - “quality checks”
  - Mandatory RN inservice
  - Move monitor bank down
  - Monitor techs IN ED
- Design:
  - No ability to “learn” patient-specific rhythms
  - No feedback for arrhythmia alarm disable



Manufacturer Response

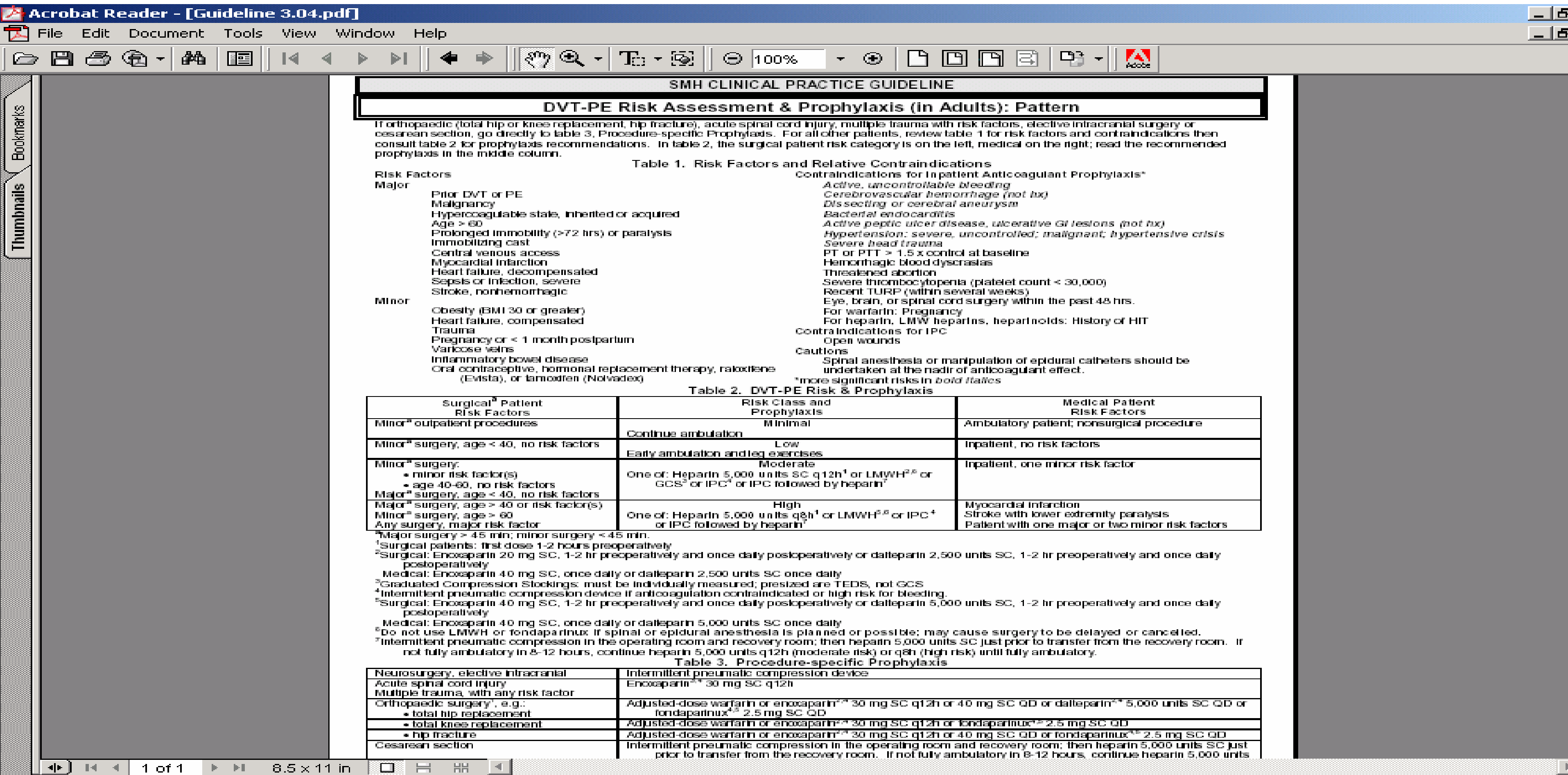
"Monitor was determined to be operating as configured according to manufacturer's specification"

Traditional approach of device industry:

"We design, test, and build high-quality medical products. It is the responsibility of users to avoid making dangerous errors when using them."

Wrong Dose, Wrong Med

A hard-to-read guideline...



SMH CLINICAL PRACTICE GUIDELINE

DVT-PE Risk Assessment & Prophylaxis (in Adults): Pattern

If orthopaedic (total hip or knee replacement, hip fracture), acute spinal cord injury, multiple trauma with risk factors, elective intracranial surgery or cesarean section, go directly to table 3, Procedure-specific Prophylaxis. For all other patients, review table 1 for risk factors and contraindications then consult table 2 for prophylaxis recommendations. In table 2, the surgical patient risk category is on the left, medical on the right; read the recommended prophylaxis in the middle column.

Table 1. Risk Factors and Relative Contraindications

Risk Factors

Major
- Prior DVT or PE
- Malignancy
- Hypercoagulable state, inherited or acquired
- Age > 60
- Prolonged immobility (>72 hrs) or paralysis
- Immobilizing cast
- Central venous access
- Myocardial infarction
- Heart failure, decompensated
- Sepsis or infection, severe
- Stroke, nonhemorrhagic

Minor
- Obesity (BMI 30 or greater)
- Heart failure, compensated
- Trauma
- Pregnancy or < 1 month postpartum
- Varicose veins
- Inflammatory bowel disease
- Oral contraceptive, hormonal replacement therapy, raloxifene (Evista), or tamoxifen (Nolvadex)

Contraindications for Inpatient Anticoagulant Prophylaxis*
- ***Active, uncontrollable bleeding***
- ***Cerebrovascular hemorrhage (not hx)***
- ***Dissecting or cerebral aneurysm***
- ***Bacterial endocarditis***
- ***Active peptic ulcer disease, ulcerative GI lesions (not hx)***
- ***Hypertension: severe, uncontrolled; malignant; hypertensive crisis***
- ***Severe head trauma***
- PT or PTT > 1.5 x control at baseline
- Hemorrhagic blood dyscrasias
- Threatened abortion
- Severe thrombocytopenia (platelet count < 30,000)
- Recent TURP (within several weeks)
- Eye, brain, or spinal cord surgery within the past 48 hrs.
- For warfarin: Pregnancy
- For heparin, LMW heparins, heparinoids: History of HIT

Contraindications for IPC
- Open wounds

Cautions
- Spinal anesthesia or manipulation of epidural catheters should be undertaken at the nadir of anticoagulant effect.

*more significant risks in *bold italics*

Table 2. DVT-PE Risk & Prophylaxis

Surgical[a] Patient Risk Factors	Risk Class and Prophylaxis	Medical Patient Risk Factors
Minor[a] outpatient procedures	Minimal Continue ambulation	Ambulatory patient; nonsurgical procedure
Minor[a] surgery, age < 40, no risk factors	Low Early ambulation and leg exercises	Inpatient, no risk factors
Minor[a] surgery: • minor risk factor(s) • age 40-60, no risk factors Major[a] surgery, age < 40, no risk factors	Moderate One of: Heparin 5,000 units SC q12h[1] or LMWH[2,6] or GCS[3] or IPC[4] or IPC followed by heparin[7]	Inpatient, one minor risk factor
Major[a] surgery, age > 40 or risk factor(s) Minor[a] surgery, age > 60 Any surgery, major risk factor	High One of: Heparin 5,000 units q8h[1] or LMWH[5,6] or IPC[4] or IPC followed by heparin[7]	Myocardial infarction Stroke with lower extremity paralysis Patient with one major or two minor risk factors

[a]Major surgery > 45 min; minor surgery < 45 min.
[1]Surgical patients: first dose 1-2 hours preoperatively
[2]Surgical: Enoxaparin 20 mg SC, 1-2 hr preoperatively and once daily postoperatively or dalteparin 2,500 units SC, 1-2 hr preoperatively and once daily postoperatively
Medical: Enoxaparin 40 mg SC, once daily or dalteparin 2,500 units SC once daily
[3]Graduated Compression Stockings: must be individually measured; presized are TEDS, not GCS
[4]Intermittent pneumatic compression device if anticoagulation contraindicated or high risk for bleeding.
[5]Surgical: Enoxaparin 40 mg SC, 1-2 hr preoperatively and once daily postoperatively or dalteparin 5,000 units SC, 1-2 hr preoperatively and once daily postoperatively
Medical: Enoxaparin 40 mg SC, once daily or dalteparin 5,000 units SC once daily
[6]Do not use LMWH or fondaparinux if spinal or epidural anesthesia is planned or possible; may cause surgery to be delayed or cancelled.
[7]Intermittent pneumatic compression in the operating room and recovery room; then heparin 5,000 units SC just prior to transfer from the recovery room. If not fully ambulatory in 8-12 hours, continue heparin 5,000 units q12h (moderate risk) or q8h (high risk) until fully ambulatory.

Table 3. Procedure-specific Prophylaxis

Neurosurgery, elective intracranial	Intermittent pneumatic compression device
Acute spinal cord injury Multiple trauma, with any risk factor	Enoxaparin[2,4] 30 mg SC q12h
Orthopaedic surgery[1], e.g.: • total hip replacement	Adjusted-dose warfarin or enoxaparin[2,4] 30 mg SC q12h or 40 mg SC QD or dalteparin[2,4] 5,000 units SC QD or fondaparinux[4,5] 2.5 mg SC QD
• total knee replacement	Adjusted-dose warfarin or enoxaparin[2,4] 30 mg SC q12h or fondaparinux[4,5] 2.5 mg SC QD
• hip fracture	Adjusted-dose warfarin or enoxaparin[2,4] 30 mg SC q12h or 40 mg SC QD or fondaparinux[4,5] 2.5 mg SC QD
Cesarean section	Intermittent pneumatic compression in the operating room and recovery room; then heparin 5,000 units SC just prior to transfer from the recovery room. If not fully ambulatory in 8-12 hours, continue heparin 5,000 units

SMH CIS

DVT-PE Prophylaxis Pathway 03/21/04 1926

DVTTEST ,GTSIXTY M 74Y 612 / 612X03

Mr#: 000000000819 Pt#: 3169 Isol: U

Allergies: NKA

Age > 60 DVT-PE Prophylaxis Selection Screen

Non-Surgical

- ☐ No operative procedure planned during admission

Surgical Procedure (other than those listed below)

- ☐ <45 minute operative duration
- ☐ >45 minute operative duration

Procedure Specific

- ☐ Intracranial surgery
- ☐ Acute spinal cord injury
- ☐ Cesarean section
- ☐ Multiple trauma
- ☐ Hip fracture
- ☐ Total hip replacement
- ☐ Total knee replacement

-OR-

- ☐ Prophylaxis not indicated

- ☐ F1 Pt List
- ☐ F2 Option Menu
- ☐ F4 Display Risk Factors
- ☐ F5 Emergency Bypass

SMDVTA1B | TRAINING MODE | Ovr | Field Help | Suspend

Start | Microsoft PowerPoint - [... | SMH CIS | 7:26 PM

SMH CIS

DVT-PE Prophylaxis Pathway 03/21/04 1927

DVTTEST ,LTFORTY M 24Y 612 / 612X01

Mr#: 000000000817 Pt#: 3167 Isol: U

Allergies: NKA

- [ ] 1 or more major risk factors
- [ ] 1 or more minor risk factors
- [ ] No risk factors
- [ ] Prophylaxis not indicated

Major:

- prior DVT or PE
- malignancy
- hypercoaguable state
- prolonged immobility (>72hr)
- paralysis
- immobilizing cast
- central venous access
- myocardial infarction
- heart failure, decompensated
- sepsis or severe infection
- stroke (non-hemorhagic)

Minor:

- obesity (BMI >30)
- heart failure, compensated
- trauma
- pregnancy or < 1 mos postpartum (except in active labor)
- Varicose veins
- Inflammatory bowel disease
- oral contraceptive
- HRT, raloxifene or tamoxifen

- [ ] F1 Pt List
- [ ] F2 Option Menu
- [ ] F3 Previous Screen
- [ ] F4 Display Risk Factors

SMDVRF01 | TRAINING MODE | Ovr | Field Help | Suspend

SMH CIS

DVT-PE Prophylaxis Pathway 03/24/04 0035

DVTTEST ,LTFORTY M 24Y 612 / 612X01

Mr#: 000000000817 Pt#: 3167 Isol: U

Allergies: NKA

DVT-PE HIGH RISK OPERATIVE Prophylaxis Order Screen

Preferred Single Therapy: (Recommended)

- [ ] Heparin 5000 units SQ q 8 hrs/ begin preop

Sequential Therapy

- [ ] Intermittent Pneumatic Compression Stockings followed by heparin 5000 units SQ q 8 hrs

Alternative Therapies

- [ ] Intermittent Pneumatic Compression Stockings followed by LWMH
- [ ] Heparin 5000 units SQ q 8 hrs/ begin postop
- [ ] Enoxaparin 40 mg SC QD
- [ ] Dalteparin 5000 units SC QD
- [ ] Intermittent Pneumatic Compression Stockings

- [ ] Display Contraindications

- [ ] F1 Pt List
- [ ] F2 Option Menu
- [ ] F3 Previous Screen
- [ ] F4 Display Risk Factors

E0103 Cursor is not in first position of an input field

Message Help | Field Help

Start | Microsoft PowerPoint - [... | Fairbanks | SMH CIS | 12:35 AM

Result of CPOE System

- Human Factors technique called “usability testing” used to develop a system using end-user input (residents and attendings)
- Result: easy to use (non-encumbering) series of 2-3 screens for every new admit brought the provider to exactly the right prophylaxis level
- Dramatic increase in compliance rates

50% → 66% → 93%

Fairbanks RJ, Caplan S, Panzer RJ. Integrating Usability Into Development Of A Clinical Decision Support System. Proceedings of HCI-International 2005, Mira Digital Publishing (ISBN 0-8058-5807-5). July 2005; Las Vegas, Nevada.

Error Identification

- Anticipate errors, design system protections
  - Study near misses & adverse events
    - “Today’s near misses are tomorrow’s adverse events”
    - Event reporting systems
  - Strong egos breeds secretive culture
    - “People who make mistakes are bad”
    - Punitive nature (peers, employers, regions, states)
    - Hierarchical structure predominates

Error Attitudes

name-blame-train

-vs-

preclude-detect-mitigate

error as cause

-vs-

error as consequence

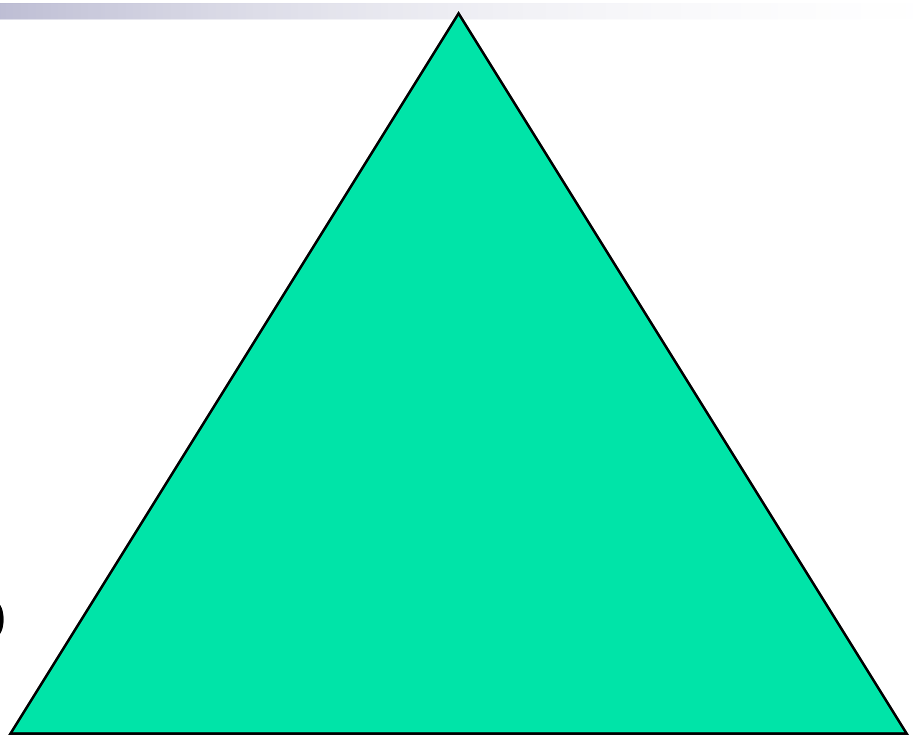
Error Attitudes

The single greatest impediment to error prevention in the medical industry is “that we punish people for making mistakes.”

--Dr. Lucian Leape; Professor, Harvard School of Public Health

Iceberg or Pyramid View of Accident Causation

- 1 serious or major injury
- 10 minor injuries
- 30 property damage injuries
- 600 incidents with no visible damage or injury



1,753,498 accidents from 297 companies, 21 different industries

Slide acknowledgment: Robert Panzer, MD

Bird, 1969

Event Reporting in Medicine

- IOM recommends reporting systems
- Failure of most in medicine
  - No incentive
  - Cumbersome
  - Classified by end-user
- Model System: VA PSRS (NASA)
- Most states still punitive
  - “state reportable”

Event Reporting in Medicine

- The last question on the NYPORTS form
- Does this breed a punitive culture?
- There needs to be a balance between standards and an understanding of the systems approach ("just culture")

Was the quality of care met ?

- ❑ Standard of care was met (If yes, no further action)
- ❑ Standard of care was met but there is room for improvement
- ❑ Standard of care was not met; attributable to systems
- ❑ Standard of care was not met; attributable to individual practitioner (If yes, complete the following:)

Practitioner's Name: _______________License #: _____

Practitioner's Name: _______________License #: _____

Culture→ REALITIES

- Human component → least reliable component of any system
- proclamations for greater vigilance do not work on the long term
- You cannot reduce adverse event rates until you <u>understand the concept of “normal error”</u>
- Otherwise:
  - Providers hide mistakes
  - Leaders close case after assigning blame and planning remediation
  - Miss many opportunities to identify system failures
  - (Incompetence will still be identified!)

What You Can Do

- When Should You Use HFE Tools?
  - During a tough Root Cause Analysis
  - Before procurement or during implementation of a new device
  - New technology assessment
- This is an introduction, so you will learn more on your own

What You Can Do

- Ask manufacturers to report their Human Factors efforts
- How were HFE techniques applied and what are the results?
- What are the most concerning use-related threats/hazards/risk?
- How have they designed for this?

What You Can Do

- Focus on contributing factors that can be changed
  - Use non-punitive QA systems (educational)
  - Use non-punitive reporting systems
  - RCAs and incident reviews should examine system factors
  - Study near misses
  - Ask staff about “accidents waiting to happen”

What You Can Do

- Facilitate culture change
- Open lines of communication (talk about error)
- Employ system safety analysis techniques
- Enact protective system changes (slices)
- **Abandon the “name, blame, train and shame” mentality– it is counterprodutive**

HFE Resources

- Human Factors & Ergonomics Society www.hfes.org
  - resources and consultant directory
- FDA Human Factors Program www.fda.gov/cdrh/humanfactors
- VA Ntl Ctr for Patient Safety www.patientsafety.gov
- Univ. Chicago www.ctlab.org
- Short Courses in Medical Human Factors
  - U. Wisconsin: www.fpm.wisc.edu/seips
  - Mayo Clinic: www.mayo.edu/cme/quality.html
- Examples from ADL: www.baddesigns.com

HFE Resources

- **Set Phasers on Stun, Steve Casey (1998)
- **The Design of Everyday Things, Don Norman (1988)
- Handbook of Human Factors and Ergonomics in Health Care and Patient Safety, Pascale Carayon (2007)
- Mistake-Proofing the Design of Health Care Processes, John Grout (2007)
- Human Error, James Reason (1990)
- Normal Accidents, Charles Perrow (1984)

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