Risk Acceptability

Safe Enough for Society

IEEE
Long Island Section

Frank O'Brien, 30 April 2015

O'Brien Compliance Management
Your medical device specialists

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O’Brien Compliance Management

- Medical device safety consulting and testing
- IEC 60601 Training
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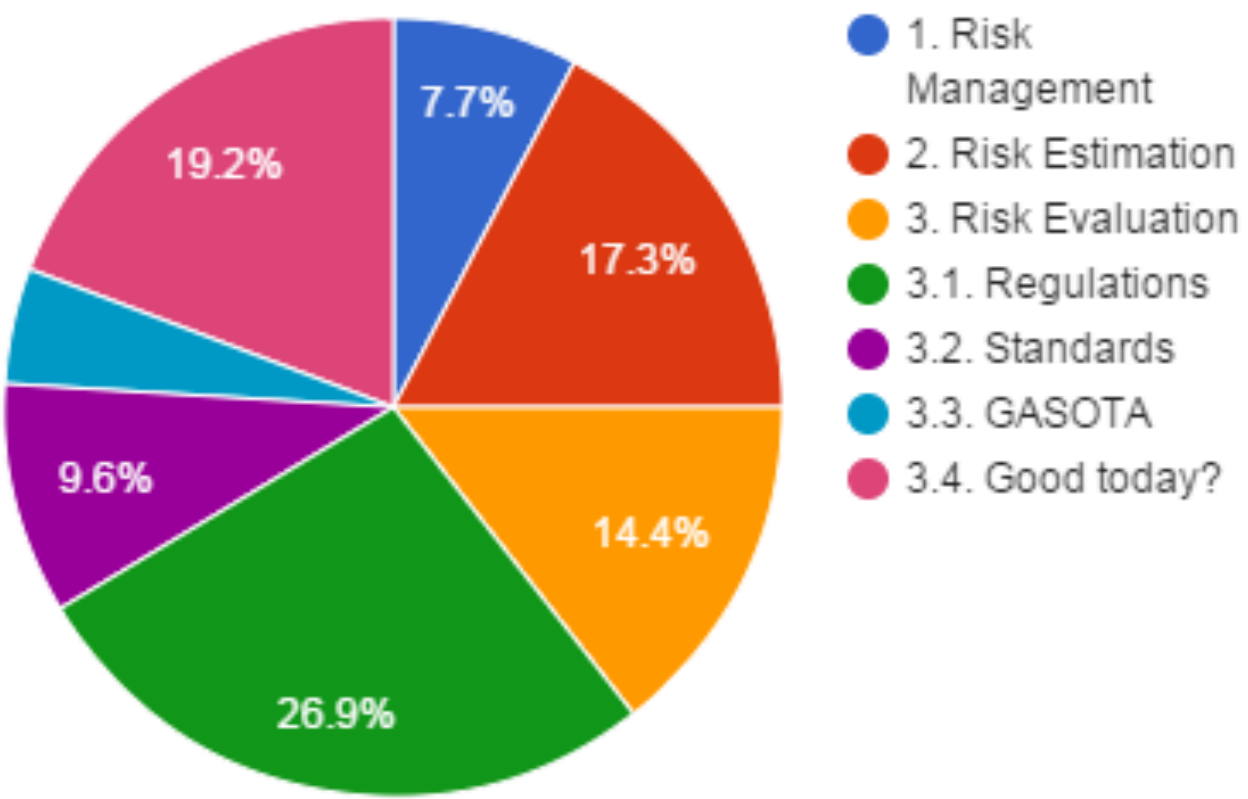
OBCM Office, Chelmsford, MA

The goal?

- Calibrate to society's risk evaluation meter
  - Meaning behind risk management terms
  - Regulatory perspective on risk management

Risk Acceptability, Agenda



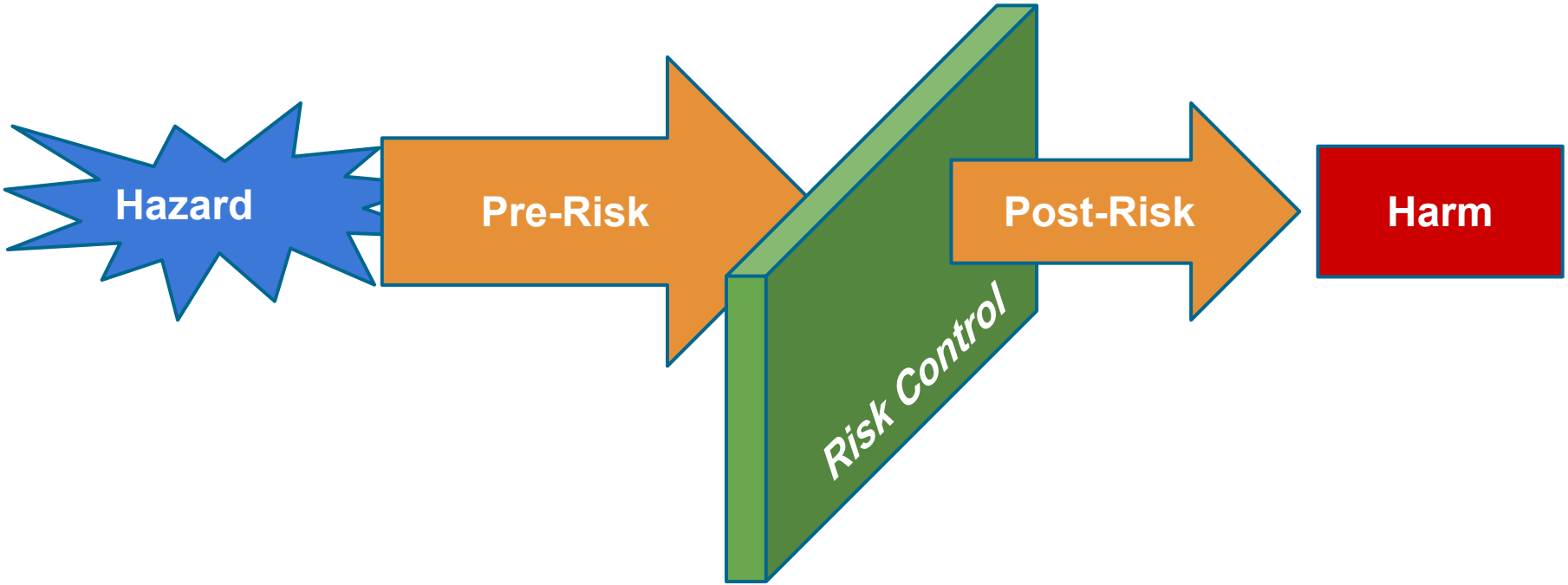
1. Risk Management

Quick Review

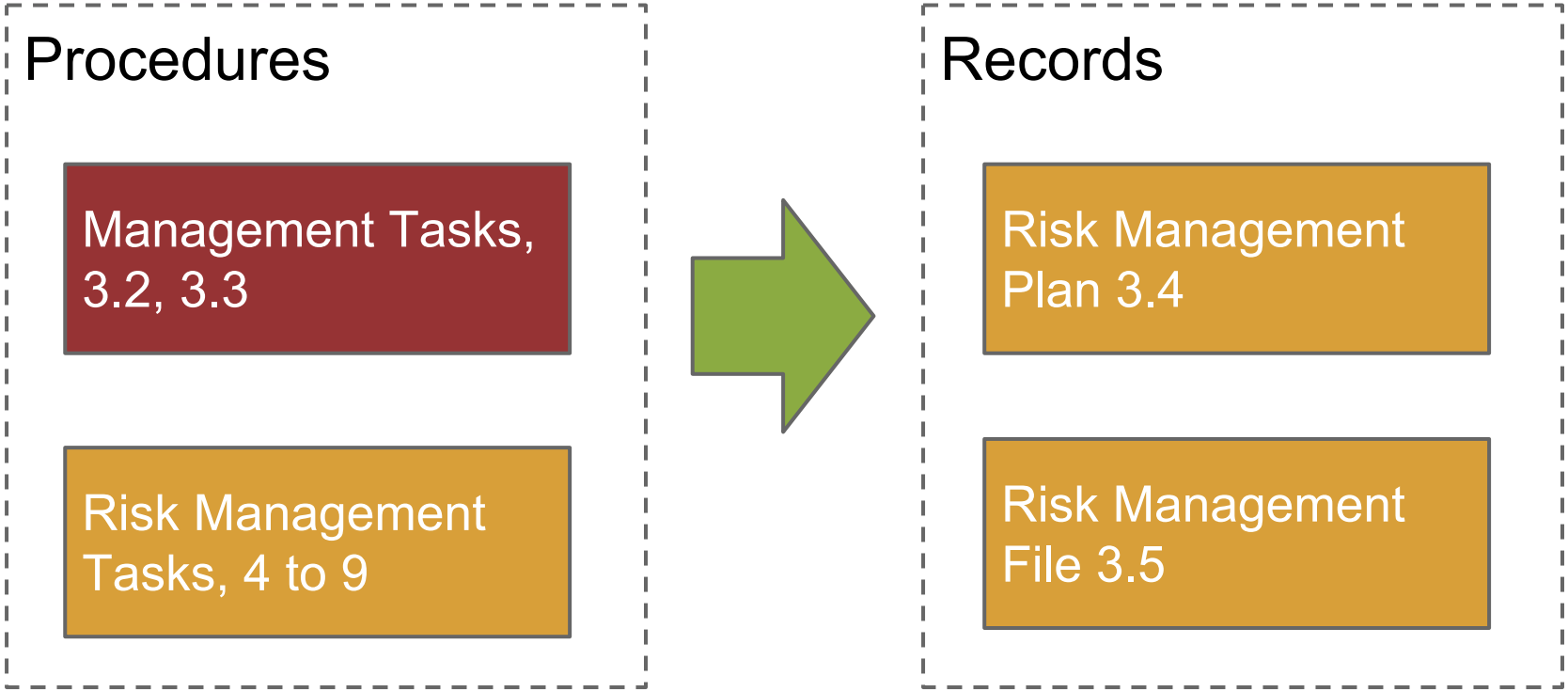
The requirements

- ISO 14971:2007
  - EN/ISO 14971:2012, Annex ZA
    - key emphasis, reduce risk as far as possible (AFAP)
- Your company's own Risk Management Procedure, which must implement
  - these RM requirements and
  - any other management policy and objectives

Cause, Risk Control, No Harmful Effect



Management process



Hypothetical risk acceptability policy

- Reduce risk “as far as possible” (AFAP), based upon
  - Applicable national or regional regulations
  - Relevant International Standards, and
  - Available information such as
    - The generally accepted state of the art (GASOTA), and
    - Known stakeholder concerns
- Periodically review

AFAP is dependent on Regulations, Standards and GASOTA, which take into account economic, technical improvements, constraints. In the context of AFAP, “possible”, “feasible” and/or “practicable” have same meaning.

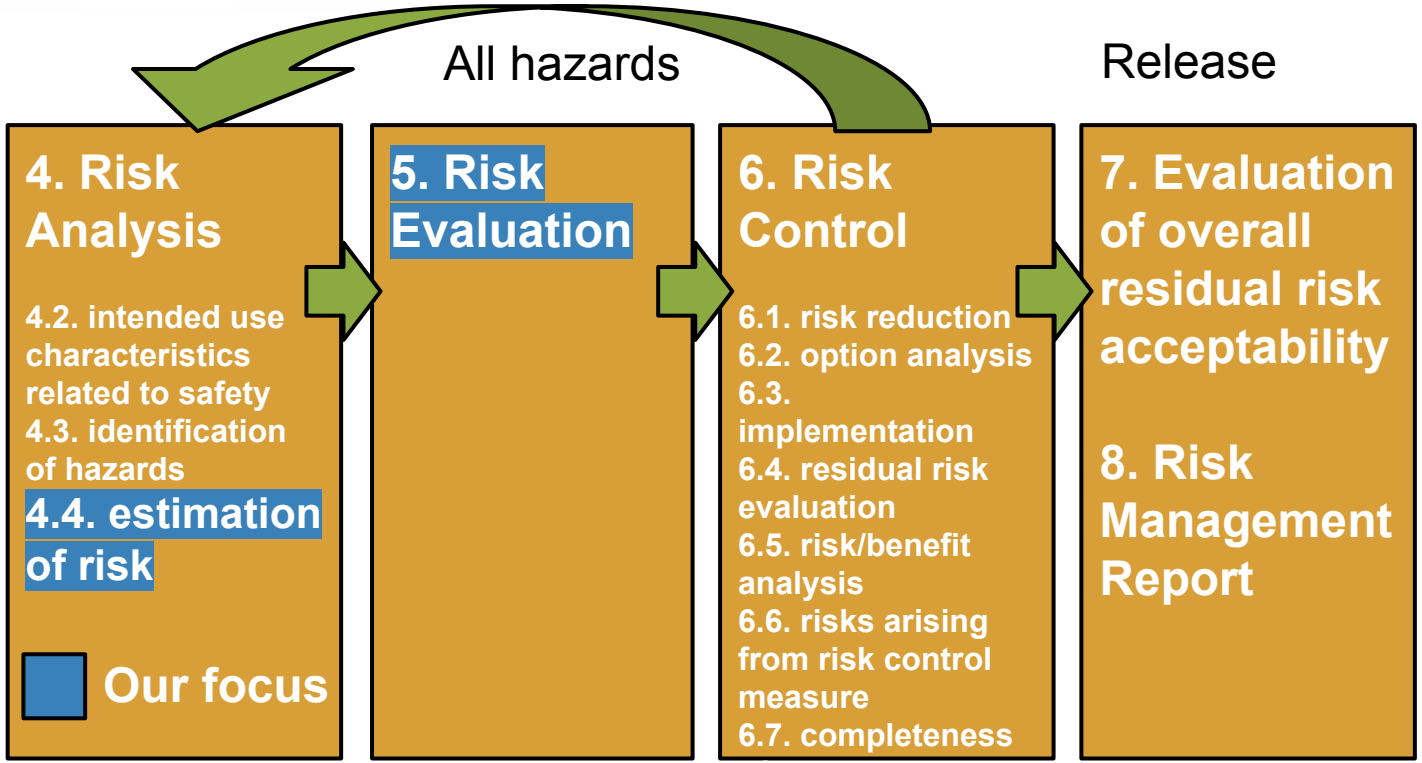
ISO 14971, 3.2, and EU MDD, ER 2

Risk Plan

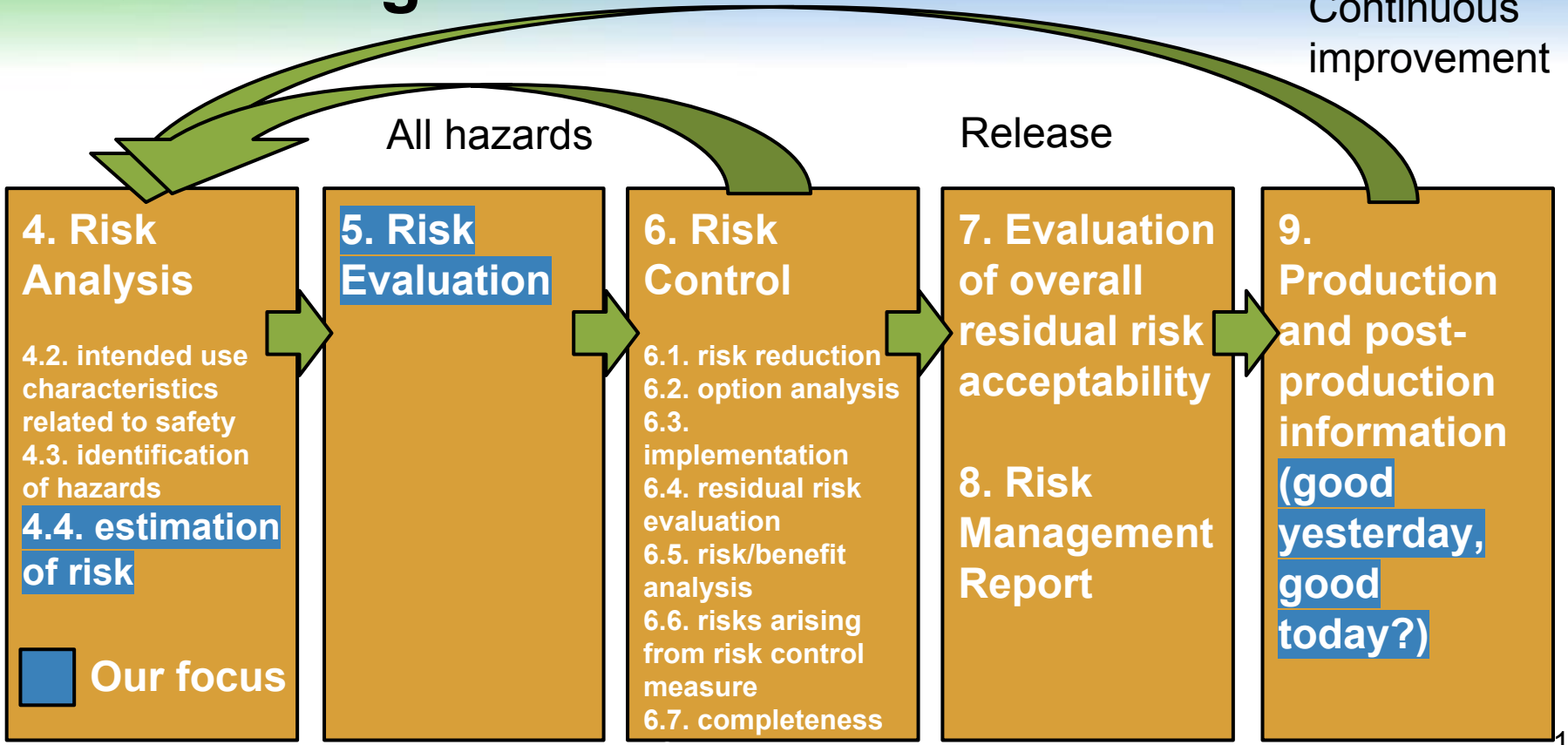
- Scope, identify, describe medical device, life-cycle (expected service life)
- Assign responsibilities and authorities
- Requirements for review of risk management activities
- Criteria for probability, severity, risk acceptability
  - Where risk policy/procedure need refinement for specific medical device, use characteristics
- Verification activities
- Activities related to collection and review of relevant production and post-production information

ISO 14971, 3.4.d

Risk Assessment and Control

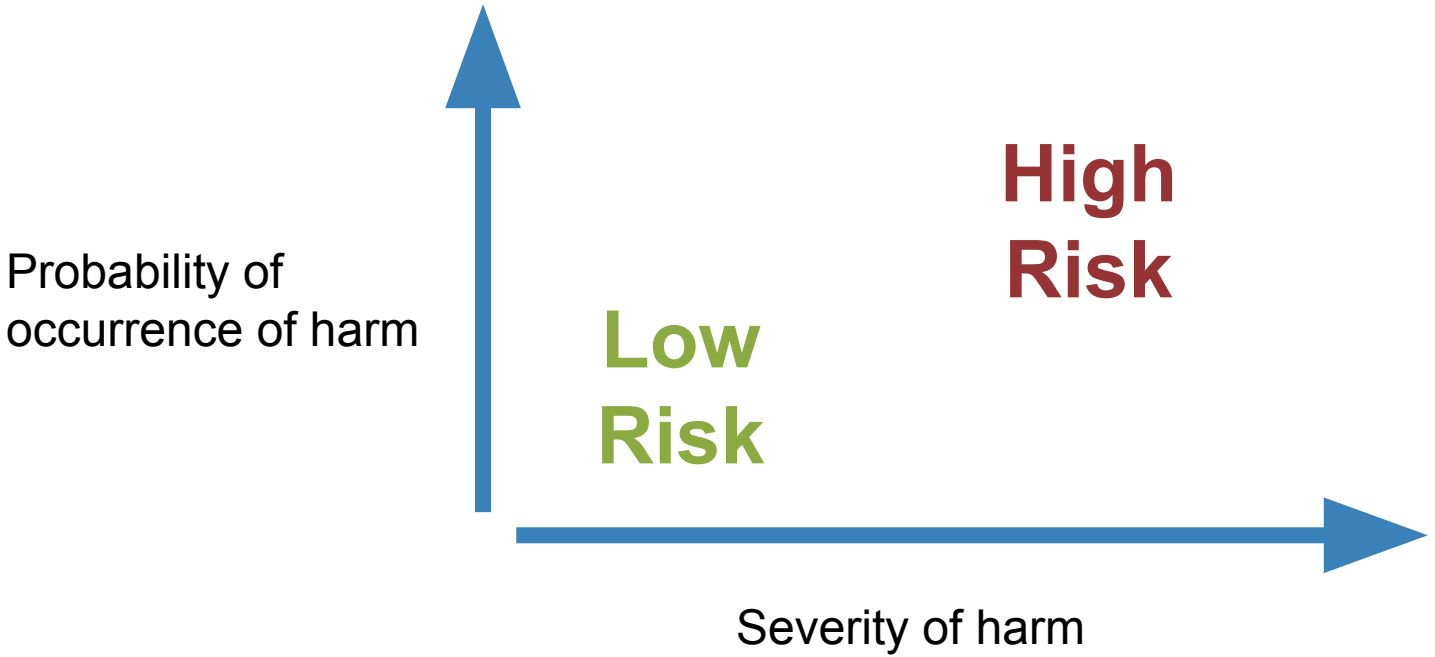


Risk Management



2. Risk Estimation

Risk dependencies

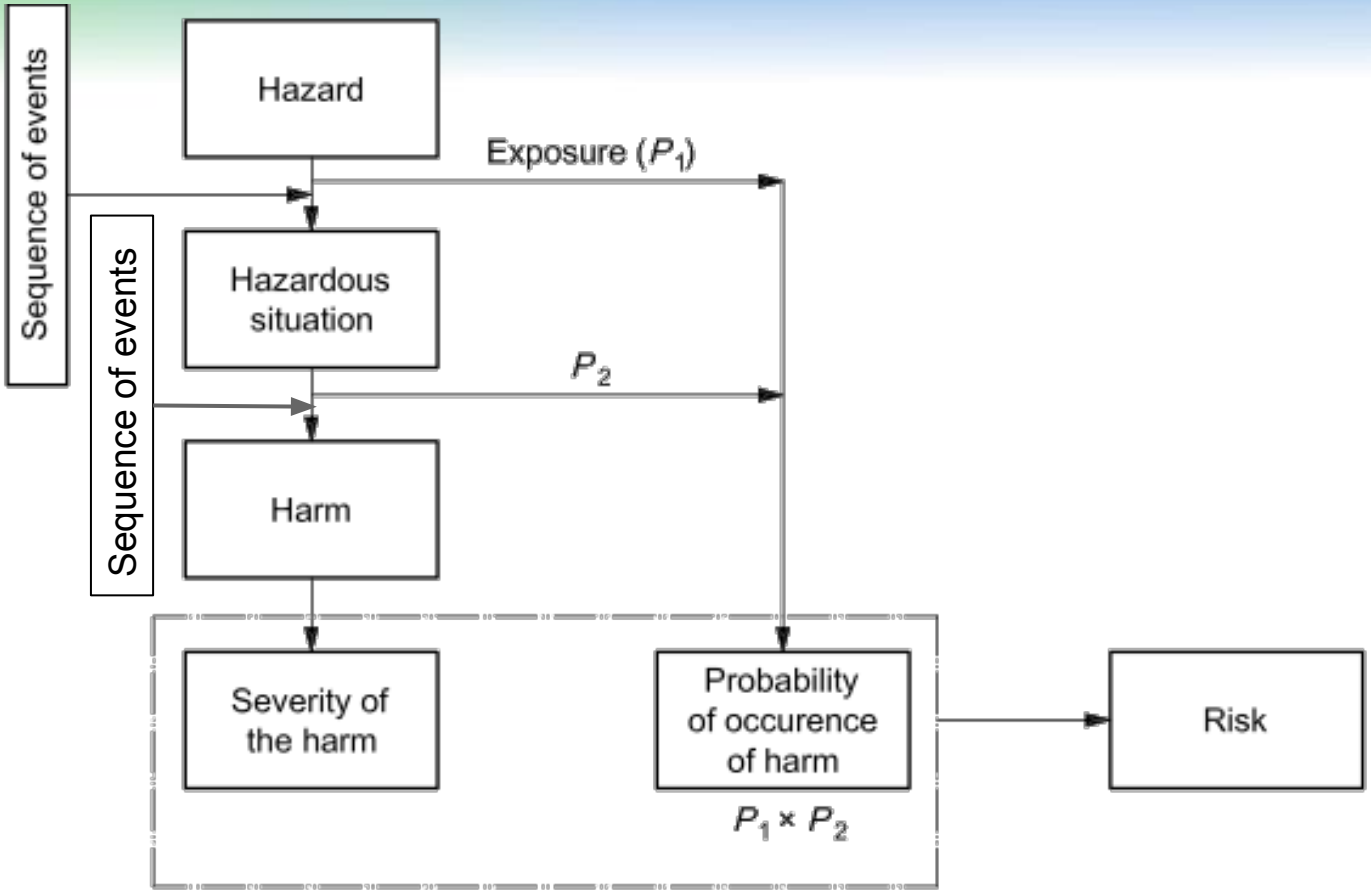


Probability of Occurrence of Harm, Qualitative

Common Term	Description (occurrences in installed base over Expected Service Life)
Frequent	Often
Probable	Likely to occur; considerable certainty that harm will occur
Occasional	Reasonable probability of occurrence of harm; good chance
Remote	Remote probability of occurrence of harm; expected that harm occur rarely/ from time to time (e.g., with no clear trend);
Negligible	Inconceivable; not possible (e.g. extremely unlikely)

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

Probability of occurrence of harm



ISO 14971, D.4

Hazard to Harm Terminology

ISO 14971	Definition
Hazard	Potential source of harm
(1st) Foreseeable Sequence of Events	Leading to [exposure of] Hazard
Hazardous situation	Exposure of hazard
(2nd) Foreseeable Sequence of Events	Leading from exposure of hazard to harm
Harm	Injury to being, property, or environment

Possible hazard categories

- Electromagnetic
- Radiation
- Mechanical energy
- Biological
- Biocompatibility
- Clinical function
- Use Error
- Information for Safety

ISO 14971, Table E.1

P1 initiating events and circumstances

- Incomplete requirements
  - parameters, performance, service, end of life
- Manufacturing processes
- Transport and storage
- Environmental and EM field factors
- Cleaning, disinfection, sterilization
- Formulation
  - Biocompatibility
- Human factors
- Failure modes
  - HW, SW, materials

ISO 14971,
Table E.2

P2 initiating events and circumstances

- Often usability (human factors) related
- To identify and estimate risk
  - Use studies, and/or
  - Historical data for similar products

Probability dependances, 1/2

- Scales for probability can include
  - Probability of harm per use
  - Probability of harm per device
  - Probability of harm per hour of use, etc.
  - Probability of harm in installed base over lifetime

ISO 14971,
Annex D.3.4

Probability dependances, 2/2

- How often is a particular medical device used?
  - What is the lifetime of the medical device?
  - Who makes up the user and patient populations?
  - What is the number of users/patients?
  - How long and under what circumstances is the user/patient exposed?

ISO 14971,
Annex D.3.4

Severity of Harm, Qualitative 1/2; person

Common Term	Person
Catastrophic	Death
Critical, severe	Permanent impairment or life threatening injury
Serious, moderate	Injury or impairment requiring professional medical intervention
Minor	Temporary injury or impairment not requiring professional medical intervention
Negligible	Inconvenience or temporary discomfort

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

Severity of Harm, Qualitative 2/2; facility or environment

Common Term	Equipment, Facility	Environment
Catastrophic	System or facility loss	Chemical release with acute or public health impact
Critical, severe	Major subsystem loss or facility damage	Chemical release with temporary environmental or public health impact
Serious, moderate	Minor subsystem loss or facility damage	Chemical release triggering external reporting requirements
Minor	Non-serious equipment or facility damage	Chemical release requiring only routine cleanup without reporting
Negligible	No damage, Equipment check,reset	No chemical release

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

Estimating risk

- Only as good as estimates for probability and severity
- Qualitative estimates can be aided by semi-qualitative estimates, or better, quantitative estimates

Risk Plan shall include

- Criteria for risk acceptability, based on the manufacturer's policy for determining acceptable risk, including criteria for accepting risks when the probability of occurrence of harm cannot be estimated;
  - This is where you document any product specific semi-quantitative guidance to aide use of probability, severity, and risk tables, or confirmation that none were required

ISO 14971, 3.4.d

Probability of Occurrence of Harm, Semi-qualitative examples

Common Term	Semi-quantitative range, probability (of Occurrence of Harm)
Frequent	≥ 10^-3
Probable, (likely)	< 10^-3 and ≥ 10^-4
Occasional, (possible)	< 10^-4 and ≥ 10^-5
Remote, (rare)	< 10^-5 and ≥ 10^-6
Negligible, (improbable, unlikely, incredible)	< 10^-6

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

Severity of Harm, Semi-qualitative examples for person

Common Term	Person	Semi-qualitative examples
Catastrophic	Death, professional medical intervention to prevent death	1 death or more; cpr, etc, prevented death
Critical, severe	Permanent impairment or life threatening injury, professional medical intervention to prevent	loss of limb, sight, hearing, 3rd deg burn
Serious, moderate	Injury or impairment requiring professional medical intervention	broken limb, 2nd degree burn, etc
Minor	Temporary injury or impairment not requiring professional medical intervention	cut finger, 1st degree burn
Negligible	Inconvenience or temporary discomfort	minor bruise, scratch, pain

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

3. Risk Evaluation

Where the magic happens

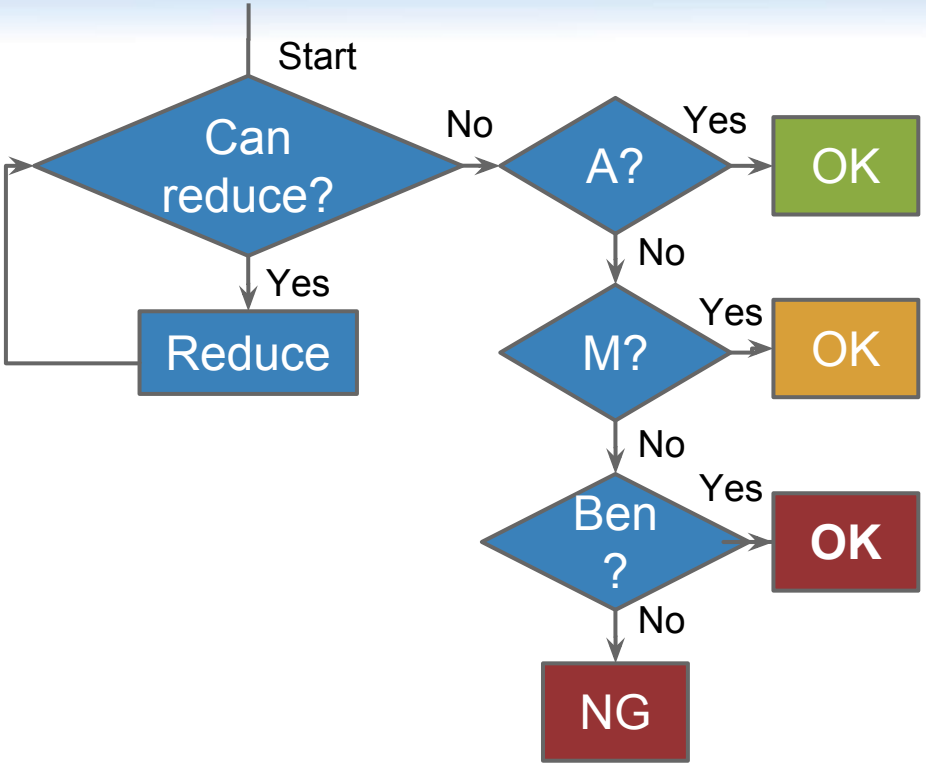
Criteria for Acceptability of Risk

Severity / Probability	Negligible	Minor	Serious	Critical	Catastrophic
Frequent	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Probable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Occasional	Acceptable	Marginal	Unacceptable	Unacceptable	Unacceptable
Remote	Acceptable	Acceptable	Marginal	Unacceptable	Unacceptable
Negligible	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

ISO 14971:2007, Annex D; IEC 61010-1:2010, Annex J; and IEC 61508-1:2010

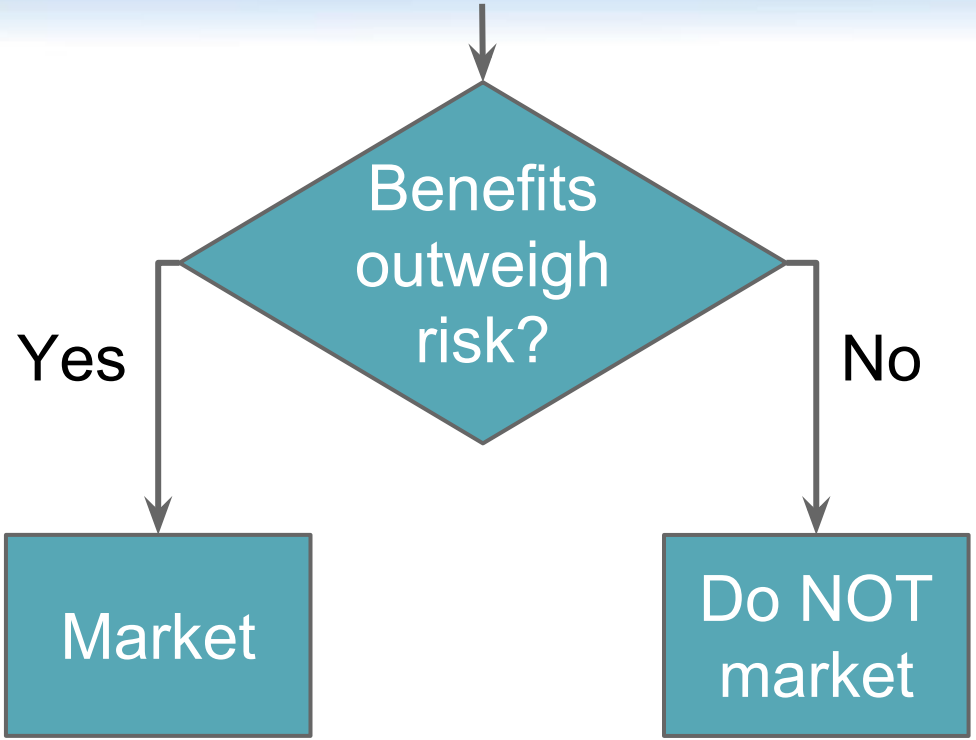
Reduce risk as far as possible (AFAP)

- Acceptable Risk must be reduced AFAP.
- Marginal Risk must be reduced AFAP and if further reduction is impossible, is justified with paper explaining risk control options investigated and why impossible to implement.
- Unacceptable Risk must be reduced AFAP and if further reduction is impossible, may be justified with Benefit Analysis.



Unacceptable Risk

- Risk/Benefit Analysis
  - Further risk reduction must be impossible
- Individual and Overall



Risk/Benefit analysis includes

- Residual risk,
- Why further risk reduction is “impossible” (infeasible, impracticable),
- Whether medical benefits (clinical evaluation) outweigh residual risk, and
- Identify relevant information for any disclosure of residual risk in the user manual or other accompanying documents to allow user/patient to weigh against benefit

Clause 6.5, 7

Alarms

- Risk control measure requiring timely response of person
  - Alarm condition
    - Hazard exists with unacceptable risk
    - Technical or physiological
  - Alarm signal
    - Indication of alarm condition
    - Visible, and audible, verbal, vibratory and/or other
  - Alarm priority (condition and signal)
    - Risk assess severity and response time for acceptable risk
    - High, Medium, Low

IEC 60601-1-8

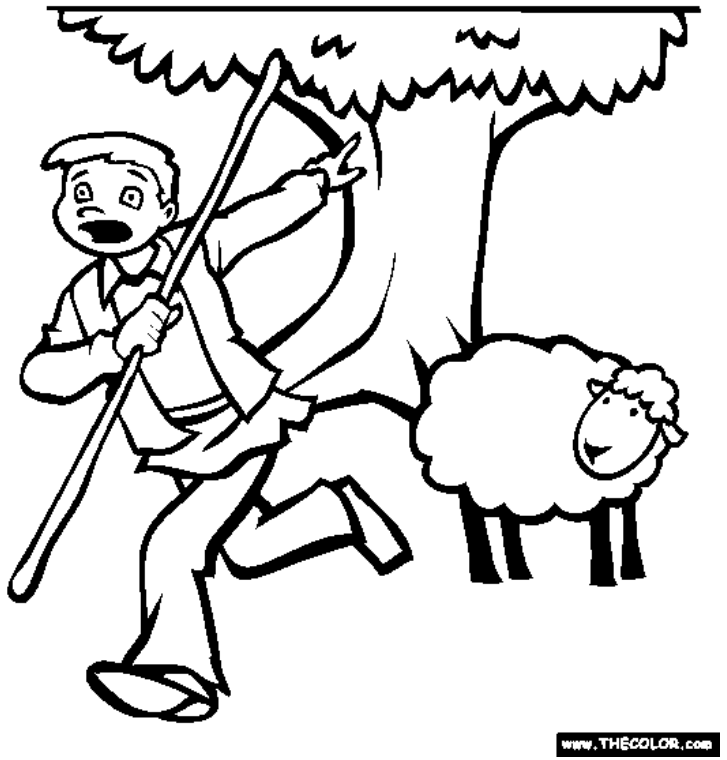
Alarm priority

	Immediate; period of time not usually sufficient for manual corrective action.	Prompt; period of time usually sufficient for manual corrective action.	Delayed; an unspecified time greater than that given under “prompt”.
Death or irreversible injury	Further investigate inherent design risk control, or High	High	Medium
Reversible injury	High	Medium	Low
Minor injury or discomfort	Medium	Low	Not risk control, (information signal), or Low

IEC 60601-1-8, 6.1.2, Table 1

Alarms and/or Information for Safety

- Employ when usability process demonstrates effectiveness as risk reduction measure
- Too many can be counter productive in reducing overall residual risk



Hypothetical product

- Patient monitoring
  - ECG, heart signal,
  - NIBP, blood pressure,
  - SpO2, O2 saturation
- CF, defib-proof
- Mains or battery
- Ethernet or WIFI
- Mount for IV pole, or bed rail

Hypothetical Characteristics of Safety Table

Characteristic related to safety	Description
Intended Use	Monitor heart function, blood pressure and blood oxygen saturation level.
User profile	Nurse, Physician and/or Service
Use environment	Indoor, within hospital, including ICU
Use scenarios (worst case environment (e.g lighting, etc), mental state, physical state (e.g perception, motor), staff support, etc)	Battery charging. Network connection. Mobile on pole. Attach to bed. Worst Case Environment: ICU, Patient Unconscious, co-located near possible fluid sources, Defib possibility, Flying leads (stranglement), Bed blankets (overheating); Bad data to Nurse call station; Higher use error due to chaotic, stressful environment, poor lighting while patient sleeping
Expected Service Life	Equipment 10 years; ECG pads, single use; SPO2, 1 year; Cuff, 1 year, Battery, 2 years; WIFI, 5 years

Hypothetical Hazard Table -- Liquid ingress event

Hazard	Foreseeable Sequence of Events	Harm	Pre-control Probability, Severity, Risk	Risk Control, and Risk Control Code (s)	Residual Probability, Severity, Risk	Verification Testing for Effectiveness	Benefit Analysis (with doc ref no)
H1. Electromagnetic energy	F3. fluid ingress, bridging of live parts	electrical shock, fire	P4, S5, U	D11. Rate for IP 22 (D); D12. Manual Warning (I)	P1, S5, A	V18. Testing to IEC 60529; U4. Usability validation	N/A

Hypothetical Hazard Table -- Support failure event

Hazard	Foreseeable Sequence of Events	Harm	Pre-control Probability, Severity, Risk	Risk Control, and Risk Control Code (s)	Residual Probability, Severity, Risk	Verification Testing for Effectiveness	Benefit Analysis (with doc ref no)
H2. Mechanical energy	F7. equipment mounting support breaks, falls on person	broken toe, contusion/bruise injury	P3, S3, U	D15. Safety factor to IEC 60601 (D); D16. 10 kg weight limit (D)	P1, S2, A	V21. Compliance testing to IEC 60601; V22. Weight verification	N/A

Hypothetical Hazard Table -- Inattentive to discharged battery event

Hazard	Foreseeable Sequence of Events	Harm	Pre-control Probability, Severity, Risk	Risk Control, and Risk Control Code (s)	Residual Probability, Severity, Risk	Verification Testing for Effectiveness	Benefit Analysis (with doc ref no)
H6. Use error	F16. attention failure, discharged battery, loss of clinical function	patient receives no/delayed necessary medical treatment	P3, S5, U	D42. 25% low battery alarm, medium priority, (P), (AM), (SC) D43. 10% low battery alarm, high priority, (P), (AH), (SC)	P1, S5, A	V25. Alarm hardware and software functional testing. U6. Usability validation	N/A

Congratulations, we're all calibrated?

Any questions?

OK, let’s dive in a bit deeper

3.1. Regulatory perspective
3.2. International standards
3.3. Generally Acknowledged State of the Art
3.4. Good yesterday. Good today?

3.1. Regulatory Perspective

Reduce Risk As Far As Possible (AFAP)

FDA, Quality System Regulation, 21 CFR 820.30, Design Controls

(g) Design validation. Each manufacturer shall establish and maintain procedures for validating the device design. Design validation shall be performed under defined operating conditions on initial production units, lots, or batches, or their equivalents. Design validation shall ensure that devices conform to defined user needs and intended uses and shall include testing of production units under actual or simulated use conditions. Design validation shall include software validation and risk analysis, where appropriate. The results of the design validation, including identification of the design, method(s), the date, and the individual(s) performing the validation, shall be documented in the DHF.

FDA, Current Thinking where improvement to safety & effectiveness needed

- Guidance for Industry and FDA Staff - Total Product Life Cycle: Infusion Pump - Premarket Notification [510(k)] Submissions
  - Assurance Case Report
    - Convincing argument to demonstrate the validity of a claim
  - Human Factors Engineering/Usability Testing
  - Clinical Evaluation
  - Risk Management

EU, Medical Device Directive, 93/42/EEC; Annex I, Essential Requirements, ER1, 1/2

1. The devices must be designed and manufactured in such a way that, when used under the conditions and for the purposes intended, they will not compromise the clinical condition or the safety of patients, or the safety and health of users or, where applicable, other persons, provided that any risks which may be associated with their intended use constitute acceptable risks when weighed against the benefits to the patient and are compatible with a high level of protection of health and safety.

EU, Medical Device Directive, 93/42/EEC; Annex I, Essential Requirements, ER1, 2/2

This shall include:
— reducing, as far as possible, the risk of use error due to the ergonomic features of the device and the environment in which the device is intended to be used (design for patient safety), and
— consideration of the technical knowledge, experience, education and training and where applicable the medical and physical conditions of intended users (design for lay, professional, disabled or other users).

EU, Medical Device Directive, 93/42/EEC; Annex I, Essential Requirements, ER2

2. The solutions adopted by the manufacturer for the design and construction of the devices must conform to safety principles, taking account of the generally acknowledged state of the art.

In selecting the most appropriate solutions, the manufacturer must apply the following principles in the following order:
— eliminate or reduce risks as far as possible (inherently safe design and construction),
— where appropriate take adequate protection measures including alarms if necessary, in relation to risks that cannot be eliminated,
— inform users of the residual risks due to any shortcomings of the protection measures adopted.

Map ER to ISO 14971 -- Threshold of risk acceptance, 1/3

MDD Directive language	ISO 14971:2007 language
Risks Reduced As Far As Possible (ER1, ER2) High level of protection of health and safety (ER1) Safety principles (ER2) Generally Acknowledged State of the Art (ER2)	Risk Acceptability, based on the manufacturer's policy, based upon applicable national or regional regulations and relevant International Standards, and taking into account available information such as the generally accepted state of the art and known stakeholder concerns (3.2)

Map ER to ISO 14971 -- Threshold of risk acceptance, 2/3, EN 14971:2012, Annex ZA

- Reminds manufacturers that “risk acceptability” is a threshold set by society, and is therefore consistent for all manufacturers rather than somehow unique or different for each manufacturer (FootNote2, FN5).
- Doesn’t want technological and economic realities to have a bearing on how far risk can be reduced at any given time, (FN3, FN5)
  - And yet Safety Principles (International Standards) and Generally Acknowledged State of the Art (ER2) take into account technological and economic realities. NB Consensus Paper agrees.

Map ER to ISO 14971 -- Threshold of risk acceptance, 3/3, EN 14971:2012, Annex ZA

As Low As Reasonably Practicable (ALARP) is NOT the normative criteria for risk acceptability that's used in ISO 14971. Rather it's an informative term (not normative) in a Note to clause 3.4 and Annex D for a marginal risk, where there's a need to investigate whether the risk can be further reduced. Annex ZA seems to have misunderstood this (FN5). NB Consensus Paper agrees.

- A similar concern could be raised about “Marginal”, with a similar argument for its support.
- Any use of terms like ALARP, or Further Analysis Required, must have a meaning consistent with the intent of AFAP (FN2).

Notified Bodies Recommendation Group

- Consensus Paper for the Interpretation and Application of Annexes Z in EN ISO 14971: 2012, Version 1.1, 13 October 2014 (final draft)

Map ER to ISO 14971 -- Means to reduce risk

MDD Directive language	ISO 14971:2007 language
Appropriate solutions (ER2)	Risk Control Measures (6.2)

Map ER to ISO 14971 -- Risk reduction hierarchy, 1/3

MDD Directive language	ISO 14971:2007 language
apply the following principles in the following order: — eliminate or reduce risks as far as possible (inherently safe design and construction), (ER2)	options in the priority order listed: a) inherent safety by design; (6.2)

Map ER to ISO 14971 -- Risk reduction hierarchy, 2/3

MDD Directive language	ISO 14971:2007 language
— where appropriate take adequate protection measures including alarms if necessary, in relation to risks that cannot be eliminated, (ER2)	b) protective measures in the medical device itself or in the manufacturing process; (6.2)

Map ER to ISO 14971 -- Protection/Protective Measures

- Examples -- when verified as effective
  - Alarms
    - Necessarily require a timely human response to complete the risk control measure
    - Generally tell a user of the need to resolve an already existing hazardous situation
    - Too many inactionable alarms can reduce effectiveness
  - Personal protective equipment
    - Lead apron, eyewear, face mask, gloves
  - Quality Controls

Map ER to ISO 14971 -- Risk reduction hierarchy, 2/3

MDD Directive language	ISO 14971:2007 language
— inform users of the residual risks due to any shortcomings of the protection measures adopted (ER2). Information Supplied by the Manufacturer (ER13)	c) information for safety (6.2)

Information for safety, 1/2

- Is risk control measure (when verified as effective)
  - Too many warnings can reduce effectiveness
- Locations, in order of effectiveness
  - Equipment marking
  - Packaging marking
  - Instructions for use
  - Technical description (e.g service manual)

Information for safety, 2/2

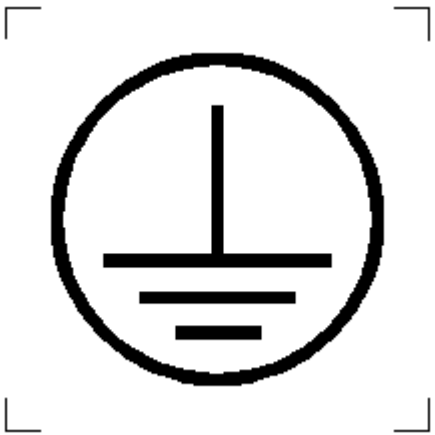
- Typical template:
  - Signal word or symbol/sign, usually associated with severity of harm (danger, warning, caution, notice),
  - Symbol or words to convey nature of hazard, (e.g. electric shock, heat, bio, radiation, etc), and
  - Symbol/sign or words to convey what to do or not to do to avoid risk of harm

Symbols, Safety Signs

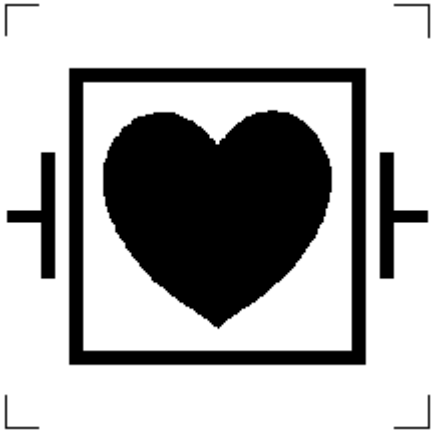
- Defined in IFU (IEC 60601-1, 7.4, 7.6)
- Obviate language differences (i.e universal language)
- Permit easier comprehension
- Use less space

Symbols

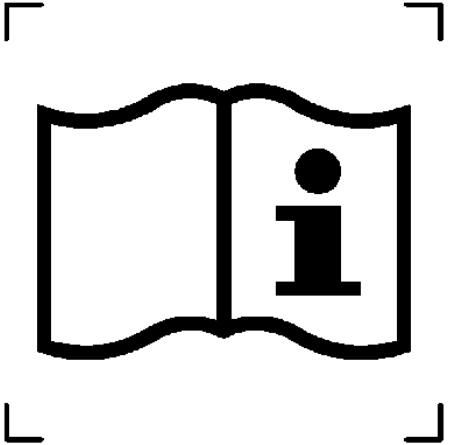
- Graphic marking or indication (IEC 60417, IEC 60787, ISO 15223)
- Examples



Protective Earth



Defib-proof Type CF Applied Part



Operating Instructions

Safety Signs

- Convey a warning, prohibition or mandatory action (ISO 7010)
- Examples

General Warning

No Pushing

Refer to Operating Instructions

Map ER to ISO 14971 -- Disclosure of residual risk, 1/3

MDD Directive language	ISO 14971:2007 language
Inform Users of the Residual Risks (ER2)	Disclosure of Residual Risk, (6.4, 6.5, 7, J.3). Is NOT risk control measure. Enables user/patient to weigh residual risks against benefits.

Map ER to ISO 14971 -- Disclosure of residual risk, 2/3, Example

- An X-ray image technique is not considered by the manufacturer as risk acceptable for children, who could be exposed multiple times in their life with inadequate records about cummulative dosage. Rather than a strict exclusion for child use, a disclosure of risk helps a doctor and family reach an informed decision for their particular clinical situation where the benefit might justify the risk.

Map ER to ISO 14971 -- Disclosure of residual risk, 3/3, EN 14971:2012, Annex ZA

- ER2 and Annex ZA, seem to overlap or mix-up Information for Safety, and Disclosure of Residual Risk (FN7). NB Consensus Paper agrees.

Map ER to ISO 14971 -- Risk/Benefit, 1/3

MDD Directive language	ISO 14971:2007 language
Weighed against the benefits to the patient (ER1)	If risk is not judged acceptable and further risk control is not practicable, the manufacturer may gather and review data and literature to determine if the medical benefits of the intended use outweigh the: ● residual risk (6.5), and ● overall residual risk (7).

Map ER to ISO 14971 -- Risk/Benefit, 2/3, residual risk terms

- Residual risk (6.5), “individual risk” (Annex ZA) is that within loop to estimate, evaluate, control risk for each hazard.
- Overall residual risk (7), “overall risk” (Annex ZA) is after all risk controls have been implemented and verified.

Map ER to ISO 14971 -- Risk/Benefit, 3/3, EN 14971:2012, Annex ZA

- “individual risk” and “overall risk” need a benefit analysis in all cases (FN1, FN4). If risk is acceptable, not sure why there’s need for benefit analysis.
- Problem is probably 6.2 uses phrase “If further risk control is not practicable”. Practicable is meant to bear in mind the state of the art (D.8.4).
  - Recall prior threshold of risk acceptance discussion.
- NB Consensus Paper clarifies need benefit analysis for overall risk

Future regulatory trends, 1/2

- Proposed European medical device regulation, http://ec.europa.eu/health/medical-devices/files/revision_docs/proposal_2012_542_en.pdf, 26 Sep 2012
- Essential requirements (ER) to be called General safety and performance requirements (GSPR)
  - GSPR1/ER1 (usability), remains unchanged, Reduce risks as far as possible
  - GSPR2/ER2 (solutions adopted), introduces term, Residual risk is judged acceptable, retains, Reduce as far as possible

Future regulatory trends, 2/2

- ISO/DIS 16142-1, Essential principles of safety and performance of medical devices; voting terminates 28 Jul 2014, iso.org
  - Annex B, Essential principals, from prior GHTF
  - EP1/ER1 (usability), remains unchanged, Reduce risks as far as possible
  - EP2/ER2 (solutions adopted), changes to, Residual risk is judged acceptable, changes to Reduce as far as practicable

3.2. International Standards

The chicken and the egg

Product Safety Standard

GASOTA Practices

Acceptable Risk

Risk Management, ISO 14971

Use of standards, 1/2

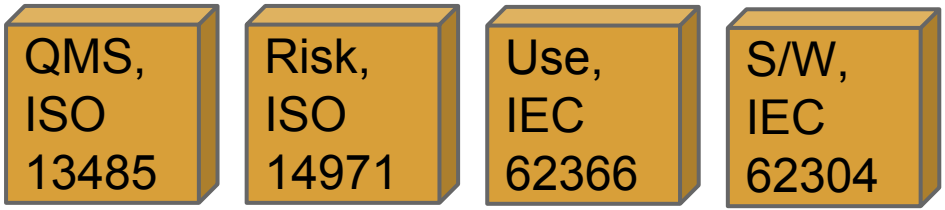
- Acceptable risk
  - EU Harmonized Standard List
  - FDA Recognized Consensus Standard Database
  - ISO/TR 16142:2006, standards in support of recognized essential principles of safety and performance
    - Webstore catalogs at IEC.ch and ISO.org

Use of standards, 2/2

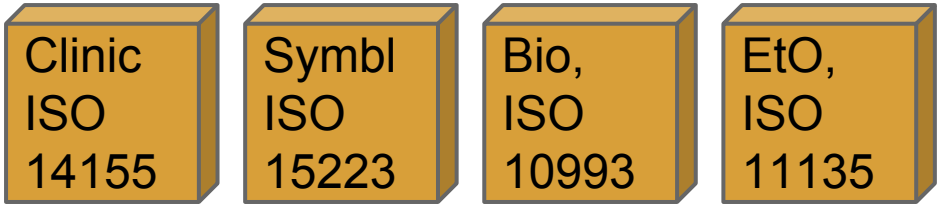
- Unless objective evidence to the contrary
  - Learn from market surveillance feedback
  - Standards may respond slower to new risk acceptability

Medical Equipment Process and Group Standards

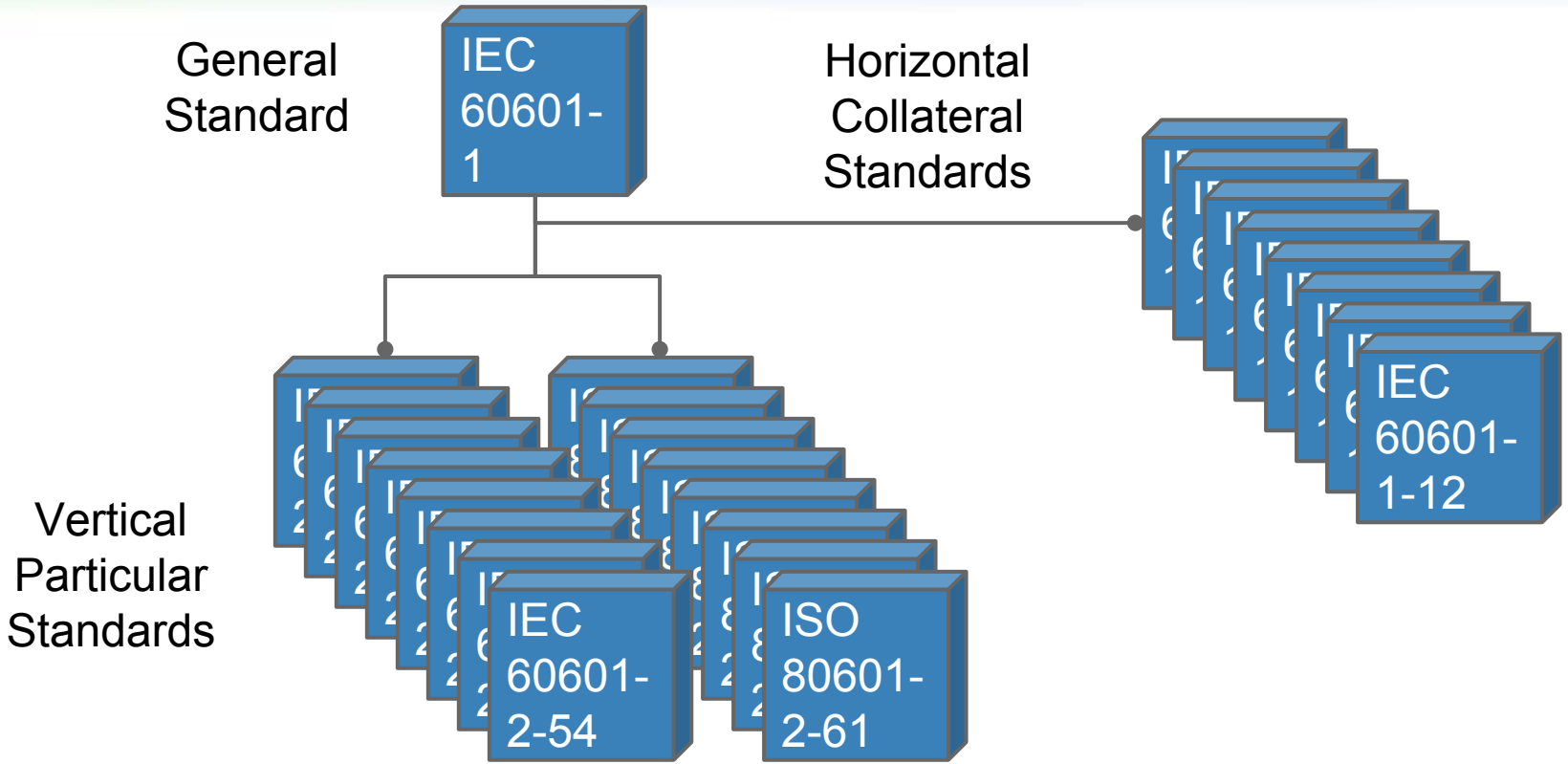
- Process Standards, for example



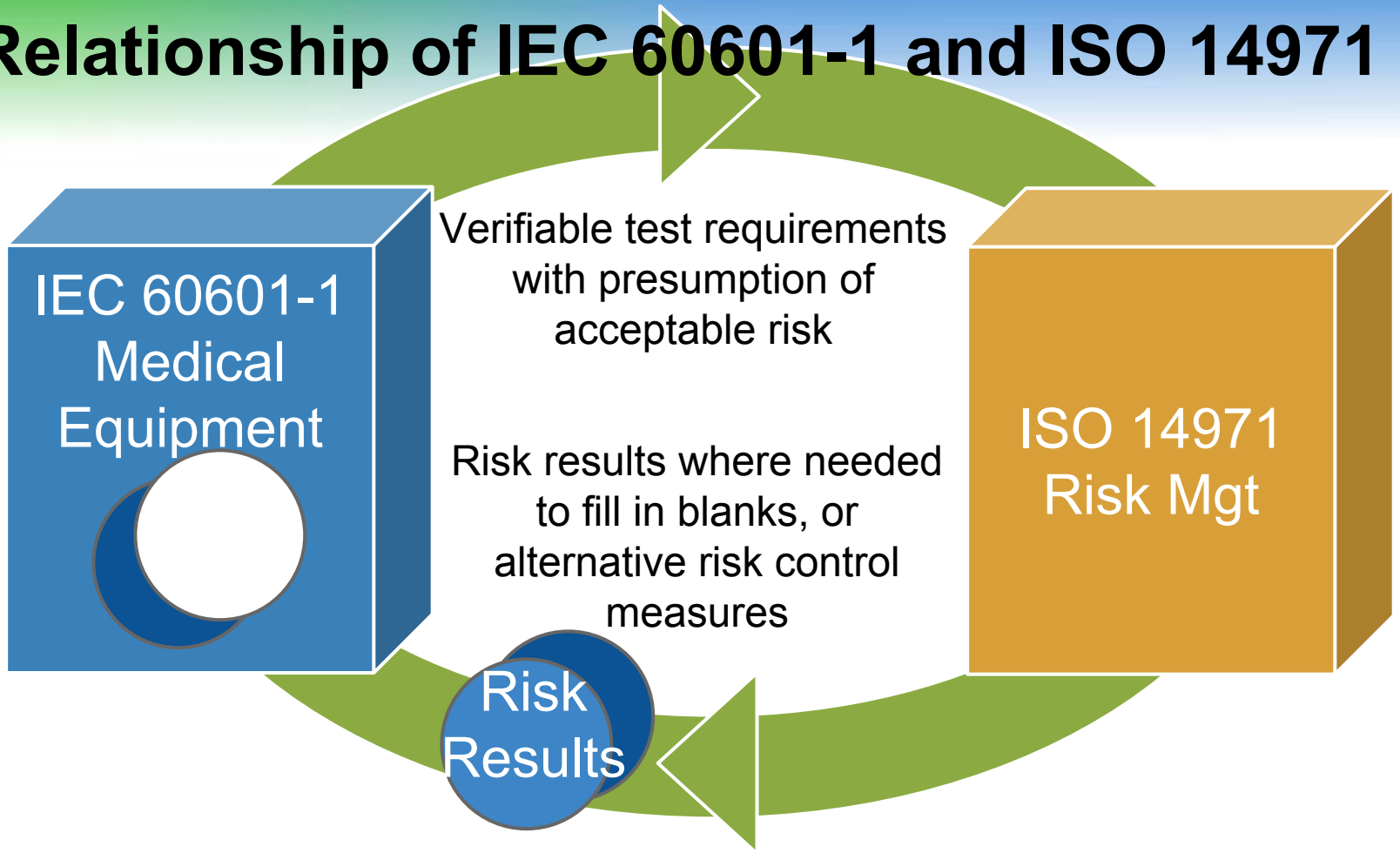
- Product, Group Standards, for example



Medical Equipment Safety, IEC 60601/ISO 80601, ed 3.1 Family



Relationship of IEC 60601-1 and ISO 14971



IEC 60601 requires Risk Management with purpose to

- Identify overlooked hazards
- Provide “risk results” to fill in blanks for
  - test applicability,
  - test method, and/or
  - test compliance criteria
    - including essential performance
- Alternative risk control strategies

Clauses 4.2.1, 4.5

Risk Results Examples

- Essential Performance (clinical), 4.3
- MOPP/MOOP, 4.6, 8.5.1
- Applicability and method of spill test, 11.6.3
- Software mitigation, 14
- Any alternative risk control measures, 4.5

IEC 60601 provides presumption of acceptable risk except where

- Risk process provides risk acceptability to IEC 60601
  - Risk process identifies overlooked hazards
  - “Risk results” are provided
  - Alternative risk control measures are provided
- Objective evidence to the contrary

Clauses 4.2.3, 4.5

3.3. Generally Acknowledged State Of The Art (GASOTA)

Define GASOTA

- Currently and generally accepted as good practice
- Technology and practice existing at the time of design
- Not necessarily the most technologically advanced solution

ISO 14971, D.4

Methods to determine GASOTA include, 1/2

- Standards used for the same or similar devices
- Best practices as used in other devices of the same or similar type
  - Compare levels of risk
- Results of accepted scientific research
  - Clinical study data, especially for new technology or new intended uses

ISO 14971, D.4

Methods to determine GASOTA include, 2/2

- Participate, seek advice from persons on standard writing committees, e.g IEC TC62
- Read trade journals
- Attend safety conferences
  - IEEE societies; product safety, EMC, biomedical
- Safety training
  - OBCM, UL, others

Empirical risk versus perceived risk

- Often differ
- Take into account the perception of risk from a wide cross section of stakeholders
- Might be necessary to give additional weighting to some risks
- Consider that identified stakeholder concerns reflect the values of society

ISO 14971, D.4

3.4. Good yesterday. Good today?

The only constant is change

Learn and continuously improve, 1/2

- Process elements in place
  - CAPA
  - Production information
  - Post-production information, PMS, Vigilance
- Informs the design process for legacy and new products

FDA QSR, ISO 13485, ISO 14971, IEC 62366

Learn and continuously improve, 2/2

- Timely periodic review important as things change, affecting actual risk estimate/evaluation
  - Technology,
  - Economics,
  - Information/data,
  - Standards
- Society’s perception of risk changes, effects estimate/evaluation.

Learn and continuously improve; Examples, 1/3

- Hair dryers used labeling to ineffectively control immersion risk leading to deaths
  - New technology, new economics, immersion detection device becomes GASOTA

Learn and continuously improve; Examples, 2/3

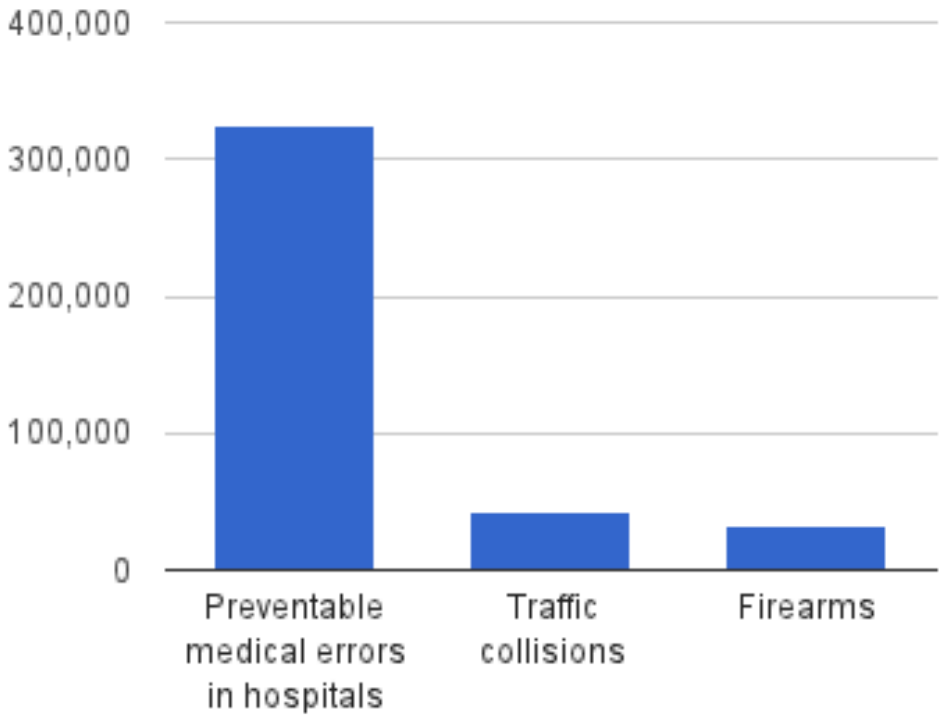
- Seat belts, Air bags
  - Became compulsory when economically, technologically feasible
- Defib paddles suitable for hospital use were cracking during ambulance use, leading to unacceptable risk
  - New data, knowledge about environment, new estimate of probability

Learn and continuously improve; Examples, 3/3

- Nuclear power plants
  - Negligible chance of catastrophic event; society's perception may be otherwise
- Post 9-11, change in perceived security risk
  - Society accepts less privacy, more perceived security
    - Privacy/security balance similar to safety risk/benefit balance

USA Deaths from Preventable Medical Errors

- At least 210,000 people, and perhaps as many as 440,000 people, die in hospitals each year as a result of preventable medical errors, includes devices, drugs, staff



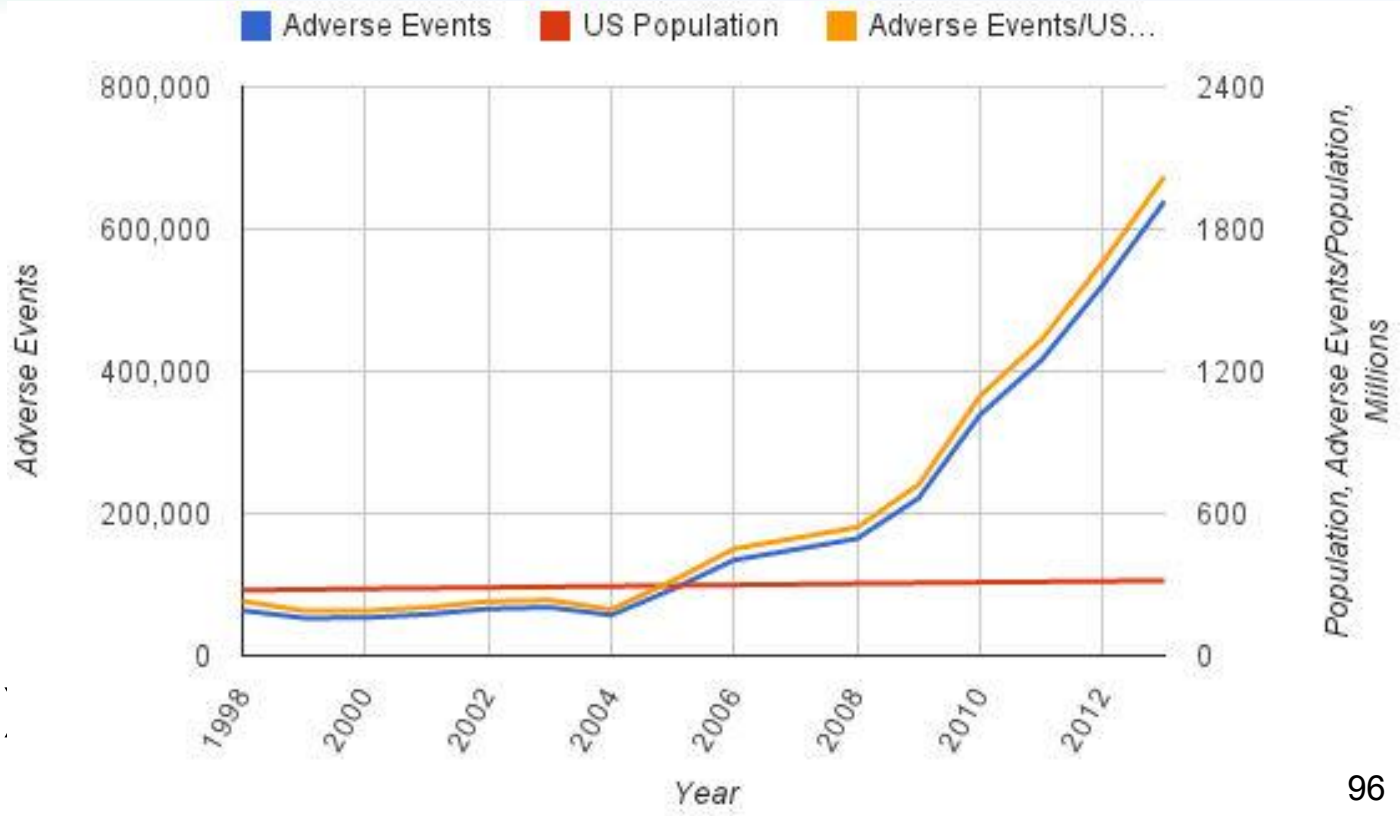
Source: A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care, Journal of Patient Safety, Sep 2013. Traffic and firearm stats are from Wikipedia.

Qualified observations

- Elements of society consider risk of firearms deaths to be unacceptable
  - Call for increased gun control and/or improved mental health care
- Medical error deaths greatly exceed firearm deaths
  - Perception seems to be lagging empirical data

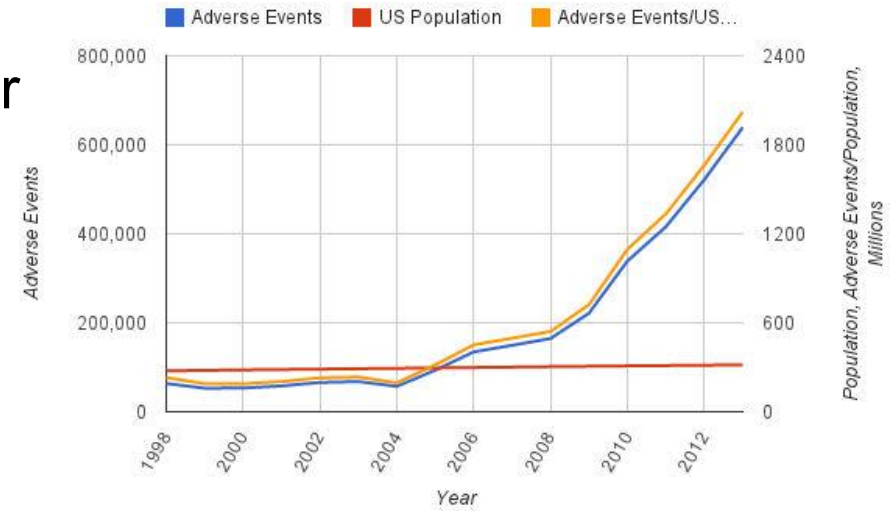
FDA MAUDE & US Census Data

- Between 1998 and 2013, 3.2 million reportable adverse events (deaths, serious injuries, and malfunctions)



Qualified observations

- Devices are probably not less safe?
- Probably more to do with higher frequency of reports to events
- What happened in 2004 and 2008 to increase reports?



USA Infusion pumps

- Between 2005 and 2009,
  - 56,000 reportable adverse events,
  - at least 700 deaths,
  - 87 manufacturer initiated product recalls
- March 2010, FDA orders Baxter to recall 200,000 infusion pumps because of "numerous flaws"
- April 23, 2010, FDA letter “manufacturers may need to conduct additional assessments of new products or changes to products currently being marketed,”

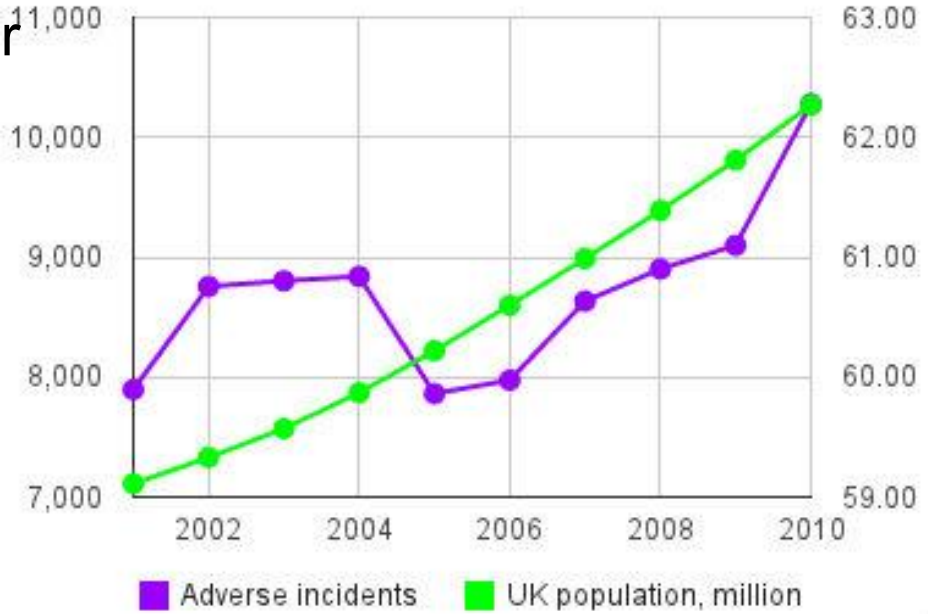
USA AED's

- Between 2005 to 2010
  - total reportable adverse events more than doubled; 2011, 2012 continue to increase
- March 25, 2013
  - FDA Proposed Order: PMA for AED System
  - Improve quality and reliability of AEDs

1 of many AED manufacturers

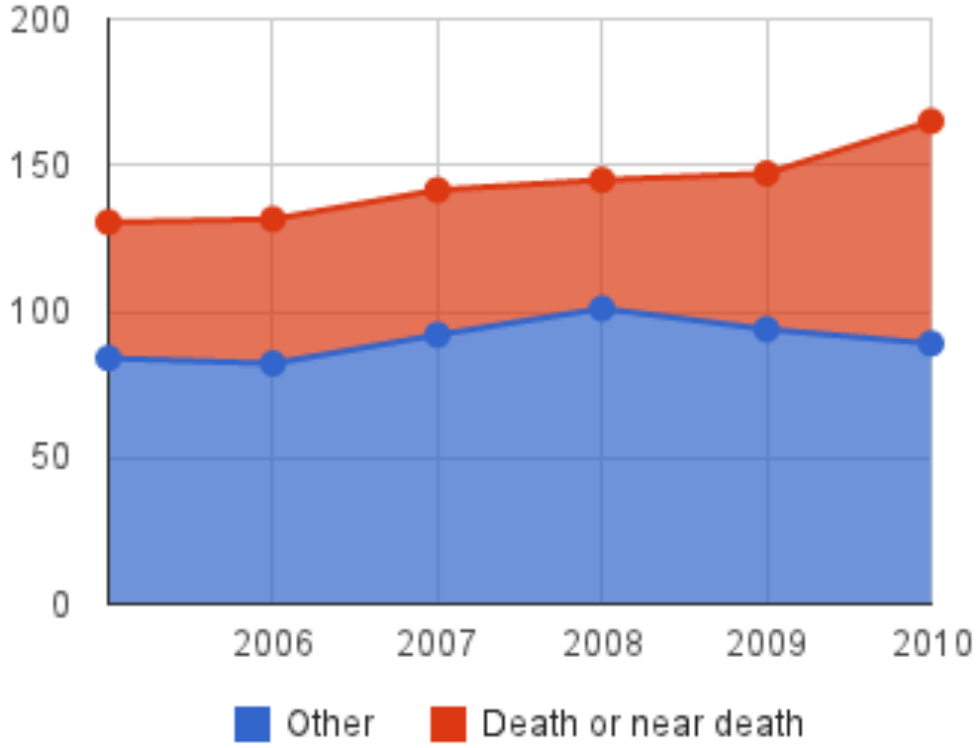
UK Adverse Incident and Population Trends

- Adverse incident causes, or has the potential to cause, unexpected or unwanted effects involving the safety of device users (including patients) or other persons



Sources: MHRA (UK) Annual AI Reports 2007, 2010; World Bank

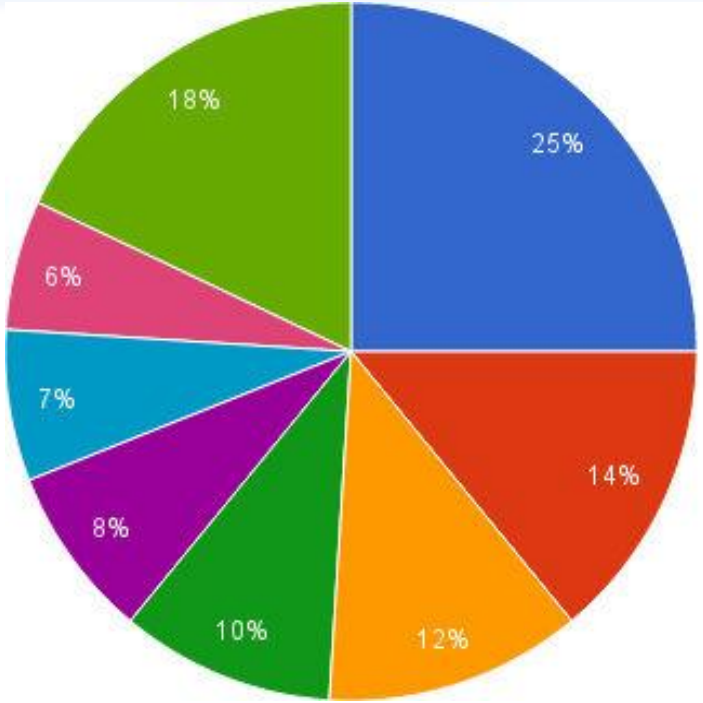
UK Adverse Incidents per 1 Million Persons



Sources: MHRA (UK) Annual AI Reports 2007, 2010; World Bank

Adverse Incidents by Device Type

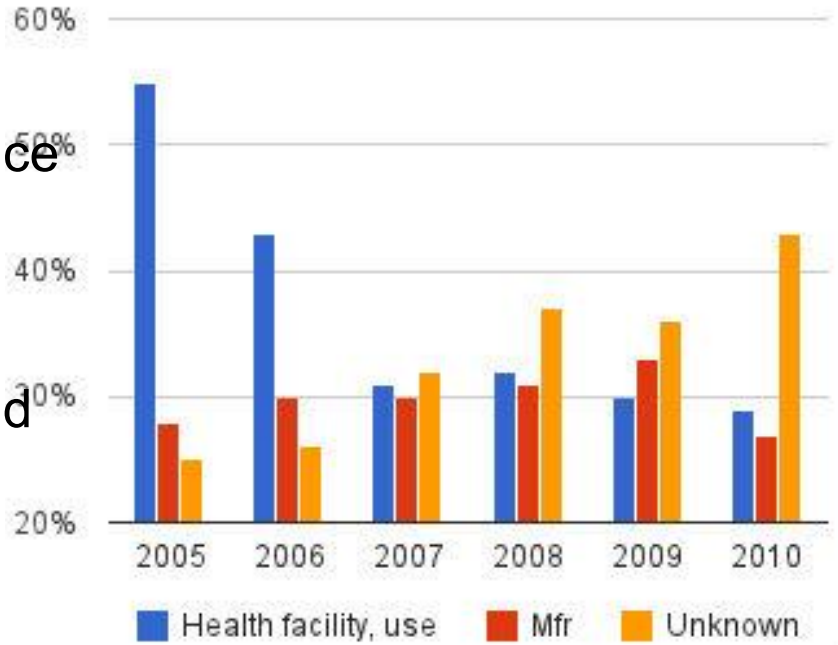
- Implants, 25%
- Surgical Equip, 14%
- Life support, incubators, monitors, 12%
- Infusion, transfusion, dialysis, 10%
- Wheeled mobility equip, 7%
- IVDs, 8%
- Diagnostic imaging, 6%
- Other, 18%



Sources: MHRA (UK) Annual AI Reports 2007, 2010

Cause of Investigated Adverse Incidents

- Healthcare facility, use
  - After delivery; use errors, performance and/or maintenance failures and degradation
- Manufacturer
  - Before delivery; design, manufacture, quality control and packaging
- Unknown
  - intermittent faults, (use error, software, EMC?), or couldn't investigate



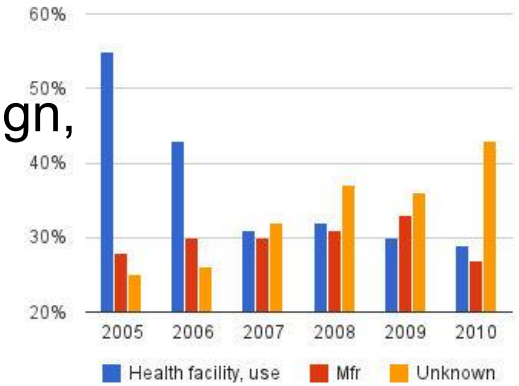
Sources: MHRA (UK) Annual AI Reports 2007, 2010

Problems with adverse incident data

- Only UK MHRA publishes report -- need more published data
- Cause investigations should target use error specifically
  - Don’t lump in with performance and/or maintenance failures and degradation
  - Categorize by device failure (e.g. transformer, switch, software, EMC), or use error
- Increase real, or due to better reporting?
- Increase in unknown causes, less assigned causes
  - Pull out suspected use error, software, EMC causes

Qualified observations

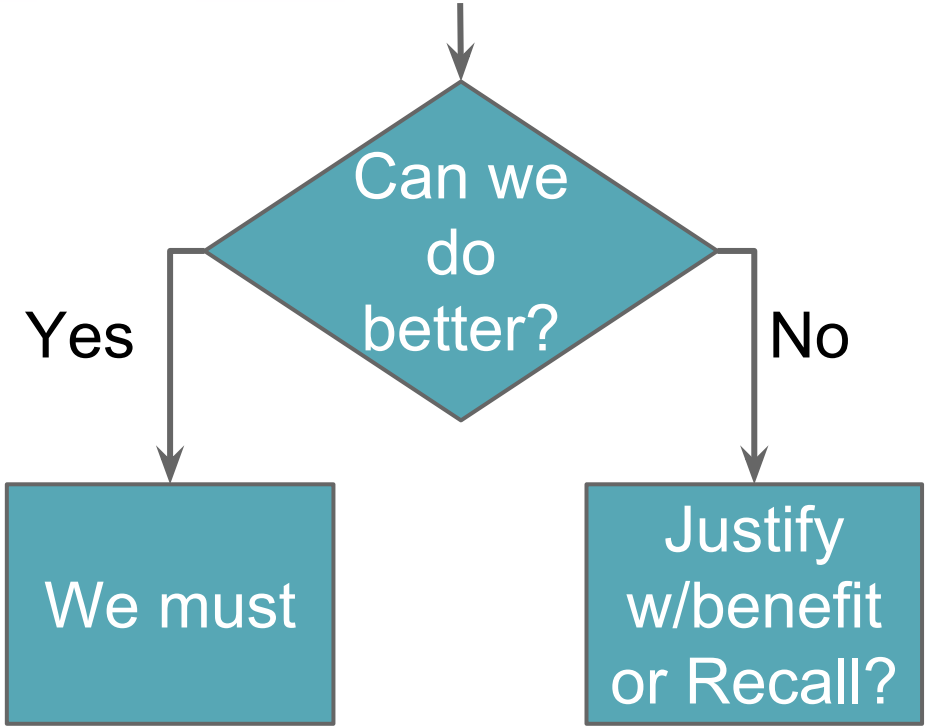
- Change in 2007
  - During 2005-06, majority of cause was health facility, use
  - During 2007-10, cause was shared between healthcare facility, use; and manufacturer design, controls; unknown increases
- 26% more adverse incidents per capita
- 29% more death or near death
- 82% involve more complicated equipment
  - Implants, surgical, patient monitors, infusion pumps, IVDs, wheelchairs, imaging, and similar



Take a good look at yesterday's risk

- Use errors causing adverse incidents/events?
  - Too complex?
- Inactionable alarms
  - Reprioritize? Customize for patient profiles?
- Manufacturing problems, too many devices recalled?

Good yesterday. Good today?



Tools to improve

- Risk Management
  - FDA, EU risk management, ISO 14971
  - FDA safety risk assurance case guidance
- Usability Engineering
  - FDA, EU usability/human factors engineering, IEC 62366
  - FDA human factors engineering guidance
- Knowledge gained from continuously improving processes transfers to staff sustaining legacy devices and designing new devices

Calibrated?

- Actual product risk discussions are necessary part of where further calibration will occur

Risk Acceptability, Summary

1. Risk Management (review)
2. Risk Estimation (review)
3. Risk Evaluation (our focus)
   - 3.1. Regulatory perspective
   - 3.2. Generally Acknowledged State of the Art
   - 3.3. Good yesterday. Good today?
   - 3.4. International standards