

**American
National
Standard**

ANSI/AAMI/ISO 14971:2000
& 14971:2000/A1:2003

**Medical devices—
Application of
risk management
to medical devices**

The Objectives and Uses of AAMI Standards and Recommended Practices

It is most important that the objectives and potential uses of an AAMI product standard or recommended practice are clearly understood. The objectives of AAMI's technical development program derive from AAMI's overall mission: the advancement of medical instrumentation. Essential to such advancement are (1) a continued increase in the safe and effective application of current technologies to patient care, and (2) the encouragement of new technologies. It is AAMI's view that standards and recommended practices can contribute significantly to the advancement of medical instrumentation, provided that they are drafted with attention to these objectives and provided that arbitrary and restrictive uses are avoided.

A voluntary *standard* for a *medical device* recommends to the manufacturer the information that should be provided with or on the product, basic safety and performance criteria that should be considered in qualifying the device for clinical use, and the measurement techniques that can be used to determine whether the device conforms with the safety and performance criteria and/or to compare the performance characteristics of different products. Some standards emphasize the information that should be provided with the device, including performance characteristics, instructions for use, warnings and precautions, and other data considered important in ensuring the safe and effective use of the device in the clinical environment. Recommending the disclosure of performance characteristics often necessitates the development of specialized test methods to facilitate uniformity in reporting; reaching consensus on these tests can represent a considerable part of committee work. When a drafting committee determines that clinical concerns warrant the establishment of *minimum* safety and performance criteria, referee tests must be provided and the reasons for establishing the criteria must be documented in the rationale.

A *recommended practice* provides guidelines for the use, care, and/or processing of a medical device or system. A recommended practice does not address device performance *per se*, but rather procedures and practices that will help ensure that a device is used safely and effectively and that its performance will be maintained.

Although a device standard is primarily directed to the manufacturer, it may also be of value to the potential purchaser or user of the device as a fume of reference for device evaluation. Similarly, even though a recommended practice is usually oriented towards health care professionals, it may be useful to the manufacturer in better understanding the environment in which a medical device will be used. Also, some recommended practices, while not addressing device performance criteria, provide guidelines to industrial personnel on such subjects as sterilization processing, methods of collecting data to establish safety and efficacy, human engineering, and other processing or evaluation techniques; such guidelines may be useful to health care professionals in understanding industrial practices.

In determining whether an AAMI standard or recommended practice is relevant to the specific needs of a potential user of the document, several important concepts must be recognized:

All AAMI standards and recommended practices are *voluntary* (unless, of course, they are adopted by government regulatory or procurement authorities). The application of a standard or recommended practice is solely within the discretion and professional judgment of the user of the document.

Each AAMI standard or recommended practice reflects the collective expertise of a committee of health care professionals and industrial representatives, whose work has been reviewed nationally (and sometimes internationally). As such, the consensus recommendations embodied in a standard or recommended practice are intended to respond to clinical needs and, ultimately, to help ensure patient safety. A standard or recommended practice is limited, however, in the sense that it responds generally to perceived risks and conditions that may not always be relevant to specific situations. A standard or recommended practice is an important *reference* in responsible decision-making, but it should never *replace* responsible decisionmaking.

Despite periodic review and revision (at least once every five years), a standard or recommended practice is necessarily a static document applied to a dynamic technology. Therefore, a standards user must carefully review the reasons why the document was initially developed and the specific rationale for each of its provisions. This review will reveal whether the document remains relevant to the specific needs of the user.

Particular care should be taken in applying a product standard to existing devices and equipment, and in applying a recommended practice to current procedures and practices. While observed or potential risks with existing equipment typically form the basis for the safety and performance criteria defined in a standard, professional judgment must be used in applying these criteria to existing equipment. No single source of information will serve to identify a particular product as "unsafe". A voluntary standard can be used as one resource, but the ultimate decision as to product safety and efficacy must take into account the specifics of its utilization and, of course, cost-benefit considerations. Similarly, a recommended practice should be analyzed in the context of the specific needs and resources of the individual institution or firm. Again, the rationale accompanying each AAMI standard and recommended practice is an excellent guide to the reasoning and data underlying its provision.

In summary, a standard or recommended practice is truly useful only when it is used in conjunction with other sources of information and policy guidance and in the context of professional experience and judgment.

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Medical devices—Application of risk management to medical devices

Approved 16 October 2000 by
Association for the Advancement of Medical Instrumentation

Approved 5 December 2000 by
American National Standards Institute

Abstract: This American National Standard specifies a procedure by which a manufacturer can identify the hazards associated with medical devices and their accessories (including *in vitro* diagnostic medical devices), estimate and evaluate the risks, control these risks, and monitor the effectiveness of the control.

Keywords: risk, hazard, risk management, risk analysis, risk assessment, medical devices, medical equipment

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Glossary of equivalent standards

International standards adopted in the United States may include normative references to other international standards. For each international standard that has been adopted by AAMI (and ANSI), the table below gives the corresponding U.S. designation and level of equivalency to the international standard. (Note: Documents are sorted by International designation.)

Other normatively referenced international standards may be under consideration for U.S. adoption by AAMI, therefore this list should not be considered exhaustive.

International designation	U.S. designation	Equivalency
IEC 60601-2-21:1994 and Amendment 1:1996	ANSI/AAMI/IEC 60601-2-21 & Amendment 1:2000 (consolidated texts)	Identical
IEC 60601-2-24:1998	ANSI/AAMI ID26:1998	Major technical variations
ISO 5840:1996	ANSI/AAMI/ISO 5840:1996	Identical
ISO 7198:1998	ANSI/AAMI VP20:1994	Major technical variations
ISO 7199:1996	ANSI/AAMI/ISO 7199:1996	Identical
ISO 10993-1:1997	ANSI/AAMI/ISO 10993-1:1997	Identical
ISO 10993-2:1992	ANSI/AAMI/ISO 10993-2:1993	Identical
ISO 10993-3:1992	ANSI/AAMI/ISO 10993-3:1993	Identical
ISO 10993-4:1992	ANSI/AAMI/ISO 10993-4:1993	Identical
ISO 10993-5:1999	ANSI/AAMI/ISO 10993-5:1999	Identical
ISO 10993-6:1994	ANSI/AAMI/ISO 10993-6:1995	Identical
ISO 10993-7:1995	ANSI/AAMI/ISO 10993-7:1995	Identical
ISO 10993-8:2000	ANSI/AAMI/ISO 10993-8:2000	Identical
ISO 10993-9:1999	ANSI/AAMI/ISO 10993-9:1999	Identical
ISO 10993-10:1995	ANSI/AAMI/ISO 10993-10:1995	Identical
ISO 10993-11:1993	ANSI/AAMI 10993-11:1993	Minor technical variations
ISO 10993-12:1996	ANSI/AAMI/ISO/CEN 10993-12:1996	Identical
ISO 10993-13:1998	ANSI/AAMI/ISO 10993-13:1999	Identical
ISO 10993-15:2000	ANSI/AAMI/ISO 10993-15:2000	Identical
ISO 10993-16:1997	ANSI/AAMI/ISO 10993-16:1997	Identical
ISO 11134:1994	ANSI/AAMI/ISO 11134:1993	Identical
ISO 11135:1994	ANSI/AAMI/ISO 11135:1994	Identical
ISO 11137:1995	ANSI/AAMI/ISO 11137:1994	Identical
ISO 11138-1:1994	ANSI/AAMI ST59:1999	Major technical variations
ISO 11138-2:1994	ANSI/AAMI ST21:1999	Major technical variations
ISO 11138-3:1995	ANSI/AAMI ST19:1999	Major technical variations
ISO 11140-1:1995 and Technical Corrigendum 1:1998	ANSI/AAMI ST60:1996	Major technical variations
ISO 11607:200x ¹⁾	ANSI/AAMI/ISO 11607:2000	Identical
ISO 11737-1:1995	ANSI/AAMI/ISO 11737-1:1995	Identical
ISO 11737-2:1998	ANSI/AAMI/ISO 11737-2:1998	Identical
ISO TR 13409:1996	AAMI/ISO TIR 13409:1996	Identical
ISO 13485:1996	ANSI/AAMI/ISO 13485:1996	Identical
ISO 13488:1996	ANSI/AAMI/ISO 13488:1996	Identical
ISO 14155:1996	ANSI/AAMI/ISO 14155:1996	Identical
ISO 14160:1998	ANSI/AAMI/ISO 14160:1998	Identical
ISO 14161: 2000	ANSI/AAMI/ISO 14161:2000	Identical

1) FDIS approved; being prepared for publication.

International designation	U.S. designation	Equivalency
ISO 14937:2000	ANSI/AAMI/ISO 14937:2000	Identical
ISO 14969:1999	ANSI/AAMI/ISO 14969:1999	Identical
ISO 14937:2000	ANSI/AAMI/ISO 14937:2000	Identical
ISO 14971:2000	ANSI/AAMI/ISO 14971:2000	Identical
ISO 15223:2000	ANSI/AAMI/ISO 15223:2000	Identical
ISO 15225:2000	ANSI/AAMI/ISO 15225:2000	Identical
ISO TS 15843:2000	AAMI/ISO TIR15843:2000	Identical
ISO TR 15844:1998	AAMI/ISO TIR15844:1998	Identical
ISO TR 16142:1999	ANSI/AAMI/ISO TIR16142:2000	Identical

Committee representation

Association for the Advancement of Medical Instrumentation

Committee on Quality Management and Corresponding General Aspects for Medical Devices

The adoption of ISO 14971, second edition, as an American National Standard was initiated by the AAMI Committee on Quality Management and Corresponding General Aspects for Medical Devices, which also serves as a U.S. Technical Advisory Group (TAG) to the relevant work in the International Organization for Standardization (ISO). U.S. representatives from the AAMI Application of Risk Management to Medical Devices Working Group (U.S. Sub-TAG for ISO/TC 210-IEC/SC 62A JWG1-RM) played an active role in developing the ISO Standard.

The **AAMI Committee on Quality Management and Corresponding General Aspects for Medical Devices** has the following members:

Chair: Robert C. Flink
Members: Robert C. Flink, Medtronic, Inc.
Leighton Hansel, U.S. Food and Drug Administration
Edward R. Kimmelman, BME, JD, Roche Diagnostics Corp.
Harvey Rudolph, PhD, Underwriters Laboratories, Inc.
Kimberly A. Trautman, U.S. Food and Drug Administration
Alternate: Charles B. Sidebottom, Medtronic, Inc.

The **AAMI Application of Risk Management to Medical Devices Working Group** has the following members:

Cochair: Harvey Rudolph
Members: Steve B. Binion, Baxter Healthcare
Robert Britain, NEMA
Cynthia Burns, Becton Dickinson
Robert Casson, Pfizer Inc. Medical Technology Group
Roger Dabbah, U.S. Pharmacopeial
Kent Donohue, Underwriters Laboratories, Inc.
J. Glenn George, Stat-A-Matrix
Nancy George, Software Quality Management, Inc.
John Hedley-Whyte, Harvard University
Dan Hoang, Abbott Laboratories
Gordon Leichter, Getinge/Castle, Inc.
Dawn Lopez, W.L. Gore & Associates
Abe Matthews, Johnson & Johnson
Paul McDaniel, Hill Rom Co.
Allan Miyoshi, St. Jude Medical, Inc.
Dale Munday, Spacelabs Medical, Inc.
Bijan Nafea, Quinton Instrument/American Home Products
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Barry F.J. Page, Consultant, Garner, NC
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Harvey Rudolph, U.S. Food and Drug Administration
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Mike Rahn, Griffith Micro Science, Inc.

Mark N. Smith, Getinge/Castle, Inc.
Byron Tart, U.S. Food and Drug Administration

NOTE—Participation by federal agency representatives in the development of this standard does not constitute endorsement by the federal government or any of its agencies.

Background of AAMI adoption of ISO 14971:2000

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. The United States is one of the ISO members that took an active role in the development of this International Standard.

ISO 14971 was prepared jointly by Technical Committee ISO/TC 210, *Quality management and corresponding general aspects for medical devices*, and IEC/SC 62A, *Common aspects of electrical equipment in medical practice*, to fill a need for an international standard on risk management to help determine the probability of possible consequences of a postulated event relating to the application of a medical device. U.S. participation in ISO/TC 210 is organized through the U.S. Technical Advisory Group for ISO/TC 210, administered by the Association for the Advancement of Medical Instrumentation on behalf of the American National Standards Institute. The United States made a considerable contribution to this standard.

AAMI encourages its committees to harmonize their work with international documents as much as possible. Upon review of ISO 14971, the AAMI Committee on Quality Management and Corresponding General Aspects for Medical Devices and the AAMI Application of Risk Management to Medical Devices Working Group decided to adopt ISO 14971 verbatim as a revision of ANSI/AAMI/ISO 14971-1:1998.

AAMI (and ANSI) have adopted other ISO standards. See the Glossary of Equivalent Standards for a list of ISO standards adopted by AAMI which gives the corresponding U.S. designation and the level of equivalency to the ISO standard.

The concepts incorporated in this standard should not be considered inflexible or static. This standard, like any other, must be reviewed and updated periodically to assimilate progressive technological developments. To remain relevant, it must be modified as technological advances are made and as new data come to light.

Suggestions for improving this report are invited. Comments and suggested revisions should be sent to Standards Department, AAMI, 1110 N. Glebe Road, Suite 220, Arlington, VA 22201-4795.

NOTE—Beginning with the foreword on page x, this American National Standard is identical to ISO 14971:2000.

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

In the field of risk management for medical devices, Technical Committee ISO/TC 210 and IEC/SC 62A have established a joint working group, JWG 1, *Application of risk management to medical devices*.

International Standard ISO 14971 was prepared by ISO/TC 210, *Quality management and corresponding general aspects for medical devices*, and Subcommittee IEC/SC 62A, *Common aspects of electrical equipment used in medical practice*.

Requirements concerning the risk analysis component of the risk management process were developed first and published as ISO 14971-1:1998, with the intention that the requirements for risk evaluation, risk control, and post-production information evaluation could be covered in additional part(s), but all the requirements have now been incorporated into this International Standard.

This first edition of ISO 14971 cancels and replaces ISO 14971-1:1998.

For purposes of future IEC maintenance, Subcommittee 62A has decided that this publication remains valid until 2004. At this date, Subcommittee 62A, in consultation with ISO/TC 210, will decide whether the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

Annexes A to G of this International Standard are for information only.

Introduction

This International Standard should be regarded as a framework for effective management by the manufacturer of the risks associated with the use of medical devices. The requirements that it contains provide a framework within which experience, insight, and judgment are applied systematically to manage these risks.

As a general concept, activities in which an individual, organization, or government is involved can expose those or other stakeholders to hazards which may cause loss or damage of something they value. Risk management is a complex subject because each stakeholder places a different value on the probability of harm occurring and on the detriment that might be suffered on exposure to a hazard.

It is accepted that the concept of risk has two components:

- a) the probability of occurrence of harm, that is, how often the harm may occur;
- b) the consequences of that harm, that is, how severe it might be.

The acceptability of a risk to a stakeholder is influenced by these components and by the stakeholder's perception of the risk.

These concepts are particularly important in relation to medical devices because of the variety of stakeholders including medical practitioners, the organizations providing health care, governments, industry, patients, and members of the public.

All stakeholders need to understand that the use of a medical device entails some degree of risk. Factors affecting each stakeholder's perception of the risks include the socioeconomic and educational background of the society concerned and the actual and perceived state of health of the patient. The way a risk is perceived also takes into account, for example, whether exposure to the risk seems to be involuntary, avoidable, from a man-made source, due to negligence, arising from a poorly understood cause, or directed at a vulnerable group within society. The decision to embark upon a clinical procedure utilizing a medical device requires the residual risks to be balanced against the anticipated benefits of the procedure. Such judgments should take into account the intended use/intended purpose, performance, and risks associated with the medical device, as well as the risks and benefits associated with the clinical procedure or the circumstances of use. Some of these judgments may be made only by a qualified medical practitioner with knowledge of the state of health of an individual patient or the patient's own opinion.

As one of the stakeholders, the manufacturer should make judgments relating to safety of a medical device, including the acceptability of risks, taking into account the generally accepted state of the art, in order to determine the probable suitability of a medical device to be placed on the market for its intended use/intended purpose. This International Standard specifies a procedure by which the manufacturer of a medical device can identify hazards associated with a medical device and its accessories, estimate and evaluate the risks associated with those hazards, control those risks, and monitor the effectiveness of that control.

For any particular medical device, other International Standards may require the application of specific methods for controlling risk.

Medical devices—Application of risk management to medical devices

1 Scope

This International Standard specifies a procedure by which a manufacturer can identify the hazards associated with medical devices and their accessories, including *in vitro* diagnostic medical devices, estimate and evaluate the risks, control these risks, and monitor the effectiveness of the control.

The requirements of this International Standard are applicable to all stages of the life cycle of a medical device.

This International Standard does not apply to clinical judgments relating to the use of a medical device.

It does not specify acceptable risk levels.

This International Standard does not require that the manufacturer has a formal quality system in place. However, risk management can be an integral part of a quality system (see, for example, Table G.1).

2 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply:

2.1 accompanying document: Document accompanying a medical device, or an accessory, and containing important information for the user, operator, installer, or assembler of the medical device, particularly regarding safety.

NOTE—Based on IEC 60601-1:1988, definition 2.1.4.

2.2 harm: Physical injury or damage to the health of people, or damage to property or the environment.

[ISO/IEC Guide 51:1999, definition 3.1]

2.3 hazard: Potential source of harm.

[ISO/IEC Guide 51:1999, definition 3.5]

2.4 hazardous situation: Circumstance in which people, property, or the environment are exposed to one or more hazard(s).

[ISO/IEC Guide 51:1999, definition 3.6]

2.5 intended use/intended purpose: Use of a product, process, or service in accordance with the specifications, instructions, and information provided by the manufacturer.

2.6 manufacturer: Natural or legal person with responsibility for the design, manufacture, packaging, or labeling of a medical device, assembling a system, or adapting a medical device before it is placed on the market and/or put into service, regardless of whether these operations are carried out by that person himself or on his behalf by a third party.

2.7 medical device: Any instrument, apparatus, appliance, material, or other article, whether used alone or in combination, including the software necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of

- diagnosis, prevention, monitoring, treatment, or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of, or compensation for, an injury or handicap,
- investigation, replacement, or modification of the anatomy or of a physiological process,
- control of conception,

and which does not achieve its principal intended action in or on the human body by pharmacological, immunological, or metabolic means but which may be assisted in its function by such means.

[ISO 13485:1996, definition 3.1]

2.8 objective evidence: Information which can be proven true, based on facts obtained through observation, measurement, test, or other means.

[ISO 8402:1994, definition 2.19]

2.9 procedure: Specific way to perform an activity.

[ISO 8402:1994, definition 1.3]

2.10 process: Set of interrelated resources and activities which transform inputs into outputs.

[ISO 8402:1994, definition 1.2]

2.11 record: Document which furnishes objective evidence of activities performed or results achieved.

[ISO 8402:1994, definition 3.15]

2.12 residual risk: Risk remaining after protective measures have been taken.

[ISO/IEC Guide 51:1999, definition 3.9]

2.13 risk: Combination of the probability of occurrence of harm and the severity of that harm.

[ISO/IEC Guide 51:1999, definition 3.2]

2.14 risk analysis: Systematic use of available information to identify hazards and to estimate the risk.

[ISO/IEC Guide 51:1999, definition 3.10]

2.15 risk assessment: Overall process comprising a risk analysis and a risk evaluation.

[ISO/IEC Guide 51:1999, definition 3.12]

2.16 risk control: Process through which decisions are reached and protective measures are implemented for reducing risks to, or maintaining risks within, specified levels.

2.17 risk evaluation: Judgment, on the basis of risk analysis, of whether a risk which is acceptable has been achieved in a given context based on the current values of society.

NOTE—Based on ISO/IEC Guide 51:1999, definitions 3.11 and 3.7.

2.18 risk management: Systematic application of management policies, procedures, and practices to the tasks of analyzing, evaluating, and controlling risk.

2.19 risk management file: Set of records and other documents, not necessarily contiguous, that are produced by a risk management process.

2.20 safety: Freedom from unacceptable risk.

[ISO/IEC Guide 51:1999, definition 3.1]

2.21 severity: Measure of the possible consequences of a hazard.

2.22 verification: Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled.

NOTE—In design and development, verification concerns the process of examining the result of a given activity to determine conformity with the stated requirement for that activity.

[ISO 8402:1994, definition 2.17]

3 General requirements for risk management

3.1 National or regional regulatory requirements

Because of the wide variety of medical devices covered by this International Standard and the different national or regional regulatory requirements covering those devices, the requirements given in 3.3 and 3.4 apply as appropriate.

3.2 Risk management process

The manufacturer shall establish and maintain a process for identifying hazards associated with a medical device, estimating and evaluating the associated risks, controlling these risks, and monitoring the effectiveness of the control. This process shall be documented and shall include the following elements:

- risk analysis;
- risk evaluation;
- risk control; and
- post-production information.

Where a documented product design/development process exists, it shall incorporate the appropriate parts of the risk management process.

NOTE 1—A documented product design/development process can be used to deal with safety in a systematic manner, in particular to enable the early identification of hazards in complex systems and environments.

NOTE 2—A schematic representation of the risk management process is shown in Figure 1.

NOTE 3—See the bibliography.

Compliance is checked by inspection of the risk management file.

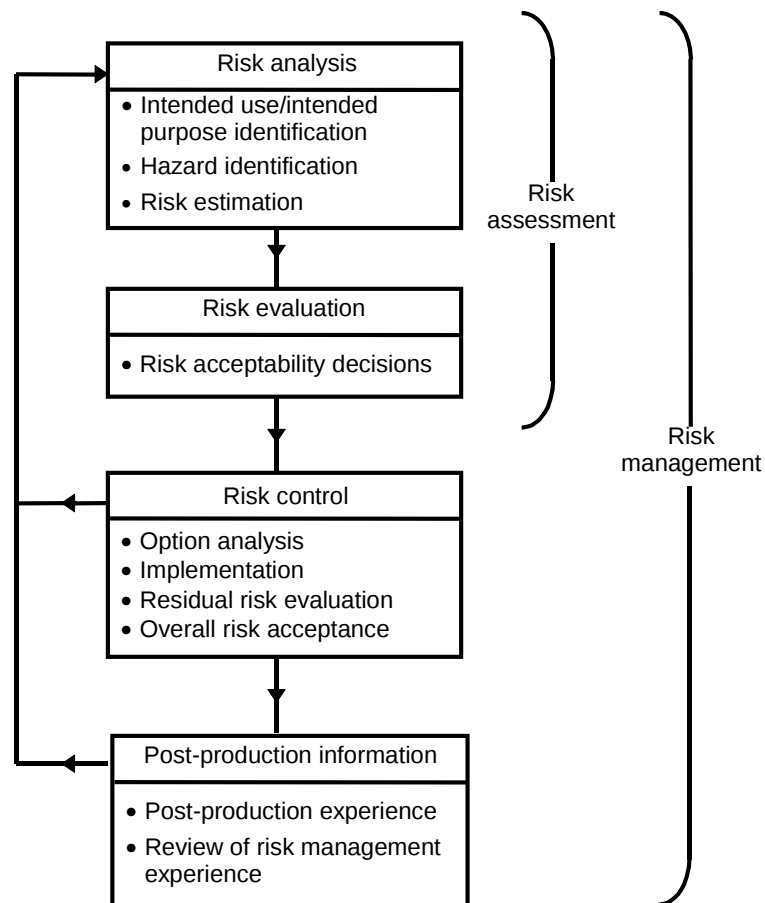


Figure 1—Schematic representation of the risk management process

3.3 Management responsibilities

The manufacturer shall

- a) define the policy for determining acceptable risk, taking into account relevant International Standards and national or regional regulations,
- b) ensure the provision of adequate resources,
- c) ensure the assignment of trained personnel (see 3.4) for management, performance of work and assessment activities, and
- d) review the results of risk management activities at defined intervals to ensure continuing suitability and the effectiveness of the risk management process.

The above shall be documented in the risk management file.

Compliance is checked by inspection of the risk management file.

3.4 Qualification of personnel

The manufacturer shall ensure that those performing risk management tasks include persons with knowledge and experience appropriate to the tasks assigned to them. This shall include, where appropriate, knowledge and experience of the medical device and its use and risk management techniques. Records of the appropriate qualifications shall be maintained.

Compliance is checked by inspection of the appropriate records.

3.5 Risk management plan

For the particular medical device or accessory being considered, the manufacturer shall prepare a risk management plan in accordance with the risk management process. The risk management plan shall be part of the risk management file.

This plan shall include the following:

- a) The scope of the plan, identifying and describing the medical device and the life cycle phases for which the plan is applicable;
- b) a verification plan;
- c) allocation of responsibilities;
- d) requirements for review of risk management activities; and
- e) criteria for risk acceptability.

NOTE—The criteria for risk acceptability will do much to determine the ultimate effectiveness of the risk management process. Refer to annex E for guidance on establishing such criteria.

If the plan changes during the life cycle of the medical device, a record of the changes shall be maintained in the risk management file.

Compliance is checked by inspection of the risk management file.

3.6 Risk management file

For the particular medical device or accessory being considered, the results of all risk management activities shall be recorded and maintained in the risk management file.

NOTE 1—The records and other documents that make up the risk management file can form part of other documents and files required, for example, by a manufacturer's quality management system.

NOTE 2—The risk management file need not physically contain all the documents relating to this International Standard. However, it should contain at least references or pointers to all required documentation. The manufacturer should be able to assemble the information referenced in the risk management file in a timely fashion.

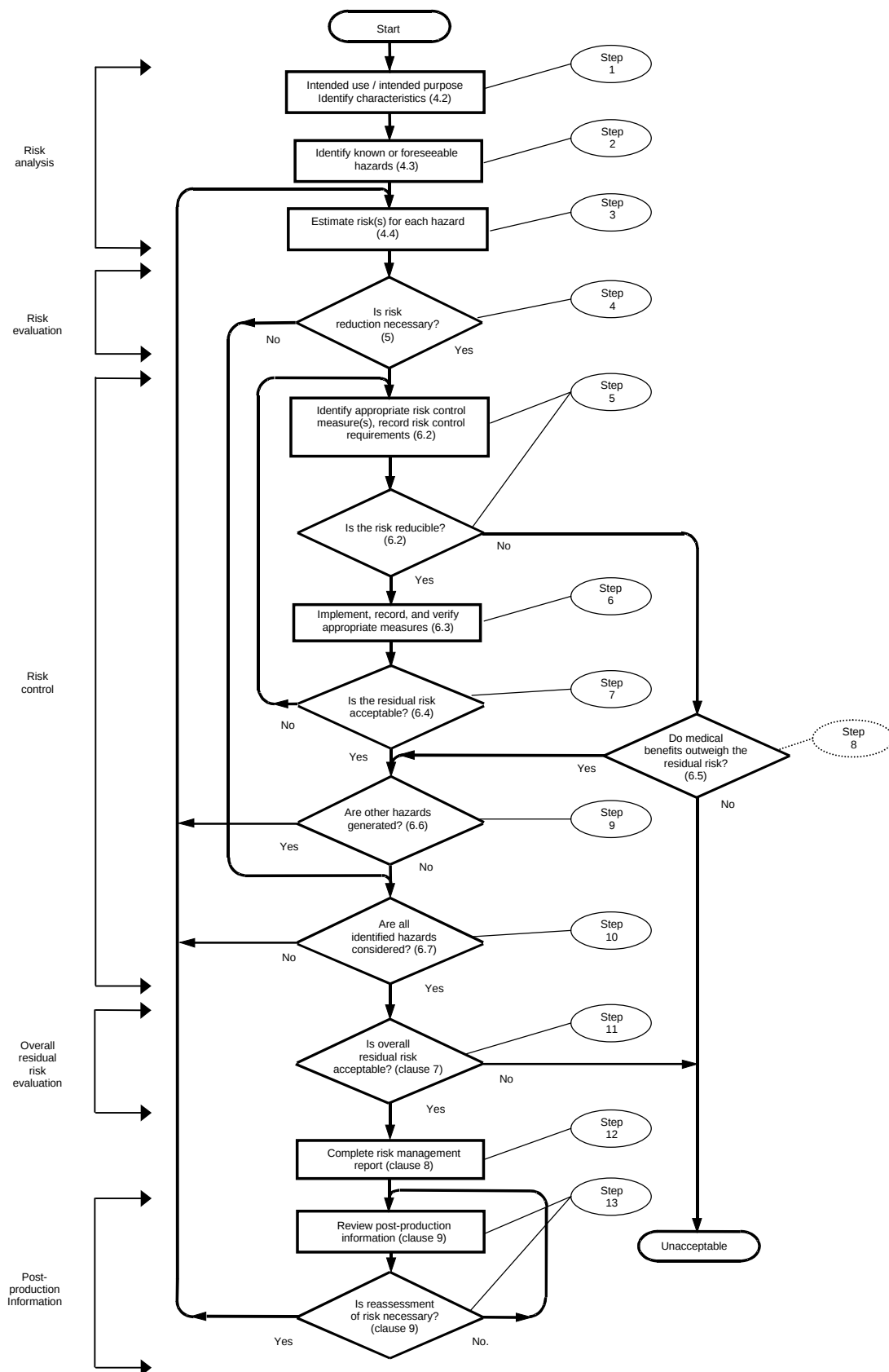


Figure 2—Overview of risk management activities as applied to medical devices

4 Risk analysis (Steps 1, 2, and 3 of Figure 2)

4.1 Risk analysis procedure

Risk analysis, as described in 4.2 to 4.4, shall be performed, and the conduct and results of the risk analysis shall be recorded in the risk management file.

NOTE—If a risk analysis is available for a similar medical device, it may be used as a reference provided it can be demonstrated that the processes are similar or that the changes that have been made will not introduce significant differences in results. This should be based on a systematic evaluation of the changes and the ways they can influence the various hazards present.

In addition to the records required in 4.2 to 4.4, the documentation of the conduct and results of the risk analysis shall include at least the following:

- a) a description and identification of the medical device or accessory that was analyzed;
- b) identification of the person(s) and organization which carried out the risk analysis;
- c) date of the analysis.

Compliance is checked by inspection of the risk management file.

4.2 Intended use/intended purpose and identification of characteristics related to the safety of the medical device (Step 1)

For the particular medical device or accessory being considered, the manufacturer shall describe the intended use/intended purpose and any reasonably foreseeable misuse. The manufacturer shall list all those qualitative and quantitative characteristics that could affect the safety of the medical device and, where appropriate, their defined limits (see Note 1). These records shall be maintained in the risk management file.

NOTE 1—Annex A contains questions that can serve as a useful guide in drawing up such a list.

NOTE 2—Additional guidance on risk analysis techniques for *in vitro* diagnostic medical devices is given in annex B.

NOTE 3—Additional guidance on risk analysis techniques for toxicological hazards is given in annex C.

Compliance is checked by inspection of the risk management file.

4.3 Identification of known or foreseeable hazards (Step 2)

The manufacturer shall compile a list of known or foreseeable hazards associated with the medical device in both normal and fault conditions. Previously recognized hazards shall be identified. This list shall be maintained in the risk management file.

Foreseeable sequences of events that may result in a hazardous situation shall be considered and recorded.

NOTE 1—The examples of possible hazards listed in annex D and in clause B.2 for *in vitro* diagnostic medical devices can be used as a memory aid.

NOTE 2—To identify hazards not previously recognized, systematic methods covering the specific situation can be used (see annex F).

Compliance is checked by inspection of the risk management file.

4.4 Estimation of the risk(s) for each hazard (Step 3)

For each identified hazard, the risk(s) in both normal and fault conditions shall be estimated using available information or data. For hazards for which the probability of the occurrence of harm cannot be estimated, a listing of the possible consequences of the hazard shall be prepared. The estimate of the risk(s) shall be recorded in the risk management file.

Any system used for qualitative or quantitative categorization of probability estimates or severity levels shall be recorded in the risk management file.

NOTE 1—Risk estimation incorporates an analysis of the probability of occurrence and the consequences. Depending on the area of application, only certain elements of the risk estimation process may need to be considered. For example, in some instances it will not be necessary to go beyond an initial hazard and consequence analysis.

NOTE 2—Risk estimation can be quantitative or qualitative. Methods of risk estimation, including those resulting from systematic faults, are described in annex E. Clause B.3 gives information useful for estimating risks for *in vitro* diagnostic medical devices.

NOTE 3—Some techniques that can be used for analysis of risks are described in annex F.

NOTE 4—Information or data for estimating risks can be obtained, for example, from

- published standards,
- scientific technical data,
- field data from similar medical devices already in use including published reported incidents,
- usability tests employing typical users,
- clinical evidence,
- results of appropriate investigations,
- expert opinion,
- external quality assessment schemes.

Compliance is checked by inspection of the risk management file.

5 Risk evaluation (Step 4)

For each identified hazard, the manufacturer shall decide, using the criteria defined in the risk management plan, whether the estimated risk(s) is so low that risk reduction need not be pursued. In this case, the requirements given in 6.2 to 6.6 do not apply for this hazard (i.e., proceed to 6.7). The results of this risk evaluation shall be recorded in the risk management file.

NOTE 1—Guidance for deciding on risk acceptability is given in clause E.3.

NOTE 2—Application of relevant standards as part of the medical device design criteria might constitute risk control activities, thus necessitating application of the requirements given in 6.3 to 6.6.

Compliance is checked by inspection of the risk management file.

6 Risk control (Steps 5 to 10)

6.1 Risk reduction

When risk reduction is required, the manufacturer shall follow the process specified in 6.2 to 6.7 to control the risk(s) so that the residual risk(s) associated with each hazard is judged acceptable.

6.2 Option analysis (Step 5)

The manufacturer shall identify risk control measure(s) that are appropriate for reducing the risk(s) to an acceptable level. Risk control shall consist of an integrated approach in which the manufacturer shall use one or more of the following in the priority order listed:

- a) inherent safety by design;
- b) protective measures in the medical device itself or in the manufacturing process;
- c) information for safety.

NOTE 1—Measures of risk control can reduce the severity of the potential harm or reduce the probability of occurrence of the harm, or both.

NOTE 2—Technical standards address inherent, protective, and descriptive safety for many medical devices. These should be consulted as part of the risk management process. See also annex G.

The risk control measures selected shall be recorded in the risk management file.

If, during option analysis, the manufacturer determines that further risk reduction is impractical, the manufacturer shall conduct a risk/benefit analysis of the residual risk (see 6.5); otherwise, the manufacturer shall proceed to implement the selected risk control measures.

Compliance is checked by inspection of the risk management file.

6.3 Implementation of risk control measure(s) (Step 6)

The manufacturer shall implement the risk control measure(s) selected in 6.2. The measure(s) used to control the risks shall be recorded in the risk management file.

The effectiveness of the risk control measures shall be verified and the results of the verification shall be recorded in the risk management file.

Implementation of the risk control measures shall be verified. This verification shall also be recorded in the risk management file.

Compliance is checked by inspection of the risk management file.

6.4 Residual risk evaluation (Step 7)

Any residual risk that remains after the risk control measure(s) are applied shall be evaluated using the criteria defined in the risk management plan. The results of this evaluation shall be recorded in the risk management file.

If the residual risk does not meet these criteria, further risk control measures shall be applied (see 6.2).

If the residual risk is judged acceptable, then all relevant information necessary to explain the residual risk(s) shall be placed in the appropriate accompanying documents supplied by the manufacturer.

Compliance is checked by inspection of the risk management file and the accompanying documents.

6.5 Risk/benefit analysis (Step 8)

If the residual risk is judged unacceptable using the criteria established in the risk management plan and further risk control is impractical, the manufacturer shall gather and review data and literature on the medical benefits of the intended use/intended purpose to determine if they outweigh the residual risk. If this evidence does not support the conclusion that the medical benefits outweigh the residual risk, then the risk remains unacceptable. If the medical benefits outweigh the residual risk, then proceed to 6.6. Relevant information necessary to explain the residual risk shall be placed in the appropriate accompanying documents supplied by the manufacturer. The results of this evaluation shall be recorded in the risk management file.

Compliance is checked by inspection of the risk management file and the accompanying documents.

6.6 Other generated hazards (Step 9)

The risk control measures shall be reviewed to identify if other hazards are introduced. If any new hazards are introduced by any risk control measures, the associated risk(s) shall be assessed (see 4.4). The results of this review shall be recorded in the risk management file.

Compliance is checked by inspection of the risk management file.

6.7 Completeness of risk evaluation (Step 10)

The manufacturer shall assure that the risk(s) from all identified hazards have been evaluated. The results of this assessment shall be recorded in the risk management file.

Compliance is checked by inspection of the risk management file.

7 Overall residual risk evaluation (Step 11)

After all risk control measures have been implemented and verified, the manufacturer shall decide if the overall residual risk posed by the medical device is acceptable using the criteria defined in the risk management plan. If the overall residual risk is judged unacceptable using the criteria established in the risk management plan, the manufacturer shall gather and review data and literature on the medical benefits of the intended use/intended purpose to determine if they outweigh the overall residual risk. If this evidence does not support the conclusion that the medical benefits outweigh the overall residual risk, then the risk remains unacceptable. The results of the overall residual risk evaluation shall be recorded in the risk management file.

Compliance is checked by inspection of the risk management file.

8 Risk management report (Step 12)

The results of the risk management process shall be recorded in a risk management report. The risk management report shall provide traceability for each hazard to the risk analysis, the risk evaluation, the implementation and verification of the risk control measures, and the assessment that the residual risk(s) is acceptable. The risk management report shall form part of the risk management file.

NOTE—This report may be held on paper or on electronic media.

Compliance is checked by inspection of the risk management report.

9 Post-production information (Step 13)

The manufacturer shall establish and maintain a systematic procedure to review information gained about the medical device or similar devices in the post-production phase. The information shall be evaluated for possible relevance to safety, especially the following:

- a) if previously unrecognized hazards are present;
- b) if the estimated risk(s) arising from a hazard is no longer acceptable;
- c) if the original assessment is otherwise invalidated.

If any of the above conditions is satisfied, the results of the evaluation shall be fed back as an input to the risk management process (see 4.4).

In the light of this safety relevant information, a review of the appropriate steps of risk management process for the medical device shall be considered. If there is a potential that the residual risk(s) or its acceptability has changed, the impact on previously implemented risk control measures shall be evaluated.

The results of this evaluation shall be recorded in the risk management file.

NOTE 1—Some aspects of post-production monitoring are the subject of national or regional regulations. In some cases, additional measures, e.g., prospective post-production evaluations, might be required.

NOTE 2—See also 4.14 of ISO 13485:1996.

NOTE 3—Information may be found at any stage of the medical device life cycle from inception to post-production phases.

Compliance is checked by inspection of the risk management process documentation and the risk management file.

Annex A

(informative)

Questions that can be used to identify medical device characteristics that could impact on safety

A.1 General

The first step in identifying hazards is to analyze the medical device for characteristics that could affect safety. One way of doing this is to ask a series of questions concerning the manufacture, use, and ultimate disposal of the medical device. If one asks these questions from the point of view of all the individuals involved (e.g., users, maintainers, patients, etc.), a more complete picture may emerge of where the potential hazards can be found. The following questions can aid the reader in identifying all the potential hazards of the medical device being analyzed.

The list is not exhaustive, and the reader is cautioned to add questions that may have applicability to the particular medical device.

A.2 Questions

A.2.1 What is the intended use/intended purpose and how is the medical device to be used?

Factors that should be considered include the intended user, the mental and physical abilities, skill, and training of the user, ergonomic aspects, the environment in which it is to be used, by whom it will be installed, and whether the patient can control or influence the use of the medical device. Special attention should be paid to intended users with special needs such as handicapped persons, the elderly, and children. Their special needs might include assistance by another person to enable the use of a medical device. Is the medical device intended to be used by individuals with various skill levels and cultural backgrounds?

What role is the medical device intended to play in the diagnosis, prevention, monitoring, treatment or alleviation of disease, compensation for injury or handicap, replacement or modification of anatomy, or control of conception? Is the medical device life sustaining or life supporting? Is special intervention necessary in the case of failure of the medical device? Are there special concerns about interface design features that could contribute to inadvertent use error (see A.2.27)?

A.2.2 Is the medical device intended to contact the patient or other persons?

Factors that should be considered include the nature of the intended contact, i.e., surface contact, invasive contact, and/or implantation and, for each, the period and frequency of contact.

A.2.3 What materials and/or components are incorporated in the medical device or are used with, or are in contact with, the medical device?

Factors that should be considered include whether characteristics relevant to safety are known.

A.2.4 Is energy delivered to and/or extracted from the patient?

Factors that should be considered include the type of energy transferred and its control, quality, quantity, and duration.

A.2.5 Are substances delivered to and/or extracted from the patient?

Factors that should be considered include whether the substance is delivered or extracted, whether it is a single substance or range of substances, the maximum and minimum transfer rates, and control thereof.

A.2.6 Are biological materials processed by the medical device for subsequent re-use?

Factors that should be considered include the type of process and substance(s) processed (e.g., auto-transfusion, dialysis).

A.2.7 Is the medical device supplied sterile or intended to be sterilized by the user, or are other microbiological controls applicable?

Factors that should be considered include whether the medical device is intended for single-use or to be re-usable, and also any packaging, the shelf-life, and any limitation on the number of re-use cycles or type of sterilization process to be used.

A.2.8 Is the medical device intended to be routinely cleaned and disinfected by the user?

Factors that should be considered include the types of cleaning or disinfecting agents to be used and any limitations on the number of cleaning cycles. In addition, the design of the medical device can influence the effectiveness of routine cleaning and disinfection.

A.2.9 Is the medical device intended to modify the patient environment?

Factors that should be considered include temperature, humidity, atmospheric gas composition, pressure, and light.

A.2.10 Are measurements taken?

Factors that should be considered include the variables measured and the accuracy and the precision of the measurement results.

A.2.11 Is the medical device interpretative?

Factors that should be considered include whether conclusions are presented by the medical device from input or acquired data, the algorithms used, and confidence limits.

A.2.12 Is the medical device intended for use in conjunction with medicines or other medical technologies?

Factors that should be considered include identifying any medicines or other medical technologies which can be involved and the potential problems associated with such interactions, as well as patient compliance with the therapy.

A.2.13 Are there unwanted outputs of energy or substances?

Energy-related factors that should be considered include noise and vibration, heat, radiation (including ionizing, non-ionizing, and ultraviolet/visible/infrared radiation), contact temperatures, leakage currents, and electric and/or magnetic fields.

Substance-related factors that should be considered include discharge of chemicals, waste products, and body fluids.

A.2.14 Is the medical device susceptible to environmental influences?

Factors that should be considered include the operational, transport, and storage environments. These include light, temperature, vibrations, spillage, susceptibility to variations in power and cooling supplies, and electromagnetic interference.

A.2.15 Does the medical device influence the environment?

Factors that should be considered include the effects on power and cooling supplies, emission of toxic materials, and the generation of electromagnetic interference.

A.2.16 Are there essential consumables or accessories associated with the medical device?

Factors that should be considered include specifications for such consumables or accessories and any restrictions placed upon users in their selection of these.

A.2.17 Is maintenance and/or calibration necessary?

Factors that should be considered include whether maintenance and/or calibration are to be carried out by the operator or user or by a specialist. Are special substances or equipment necessary for proper maintenance and/or calibration?

A.2.18 Does the medical device contain software?

Factors that should be considered include whether software is intended to be installed, verified, modified, or exchanged by the user and/or operator.

A.2.19 Does the medical device have a restricted shelf-life?

Factors that should be considered include labeling or indicators and the disposal of such medical devices.

A.2.20 Are there any delayed and/or long-term use effects?

Factors that should be considered include ergonomic and cumulative effects.

A.2.21 To what mechanical forces will the medical device be subjected?

Factors that should be considered include whether the forces to which the medical device will be subjected are under the control of the user or controlled by interaction with other persons.

A.2.22 What determines the lifetime of the medical device?

Factors that should be considered include aging and battery depletion.

A.2.23 Is the medical device intended for single use?

A.2.24 Is safe decommissioning or disposal of the medical device necessary?

Factors that should be considered include the waste products that are generated during the disposal of the medical device itself. For example, does it contain toxic or hazardous material, or is the material recyclable?

A.2.25 Does installation or use of the medical device require special training?

Factors that should be considered include commissioning and handing over to the end user and whether it is likely/possible that installation can be carried out by people without the necessary skills.

A.2.26 Will new manufacturing processes need to be established or introduced?

The introduction of new manufacturing processes into the manufacturer facilities has to be considered as a potential source of new hazard(s) (e.g., new technology, new scale of production).

A.2.27 Is successful application of the medical device critically dependent on human factors such as the user interface?

Factors that should be considered are user interface design features that can contribute to user error. Features should be designed so that they cannot be easily misused by busy users in an environment where distractions are commonplace, e.g., device control, symbols used, ergonomic features, physical design and layout, hierarchy of operation, menus for software driven devices, visibility of warnings, audibility of alarms, standardized color coding. These considerations include, but are not limited to, the following.

A.2.27.1 Does the medical device have connecting parts or accessories?

Factors that should be considered include the possibility of wrong connections, differentiation, similarity to other products' connections, connection force, feedback on connection integrity, and over- and under-tightening.

A.2.27.2 Does the medical device have a control interface?

Factors that should be considered include spacing, coding, grouping, mapping, modes of feedback, blunders, slips, control differentiation, visibility, direction of activation or change, whether the controls are continuous or discrete, and the reversibility of settings or actions.

A.2.27.3 Does the medical device display information?

Factors that should be considered include visibility in various environments, orientation, populations and perspectives, clarity of the presented information, units, color coding, and the accessibility of critical information.

A.2.27.4 Is the medical device controlled by a menu?

Factors that should be considered include complexity and number of layers, awareness of state, location of settings, navigation method, number of steps per action, sequence clarity and memorization problems, and importance of control function relative to its accessibility.

A.2.28 Is the medical device intended to be mobile or portable?

Factors that should be considered are the necessary grips, handles, wheels, brakes, mechanical stability, and durability.

Annex B

(informative)

Guidance on risk analysis for *in vitro* diagnostic medical devices

B.1 General

This annex provides additional guidance on the risk analysis of *in vitro* diagnostic medical devices, taking into account the particularities and specific aspects of these medical devices. The use of *in vitro* diagnostic medical devices does not create any direct risk to the patient or the person subjected to the examination, as they are not applied in or on the human body. Under certain circumstances, however, indirect risks may result from hazards associated with *in vitro* diagnostic medical devices, leading or contributing to erroneous decisions. In addition, use-related hazards and their associated risks should be considered.

B.2 Identification of hazards

In addition to those aspects mentioned in annex D, the following aspects should be considered in identifying potential hazards for the patient or the person subjected to examination:

- batch inhomogeneity, batch-to-batch inconsistency;
- common interfering factors;
- carry-over effects;
- specimen identification errors;
- stability problems (in storage, in shipping, in use, after first opening of the container);
- problems related to taking, preparation, and stability of specimens;
- inadequate specification of prerequisites;
- inadequate test characteristics.

Potential hazards for the user can arise from radioactive, infectious, toxic, or otherwise hazardous ingredients of reagents and from the packaging design. For instruments, the problem of potential contamination during handling, operation, and maintenance should be considered in addition to the non-specific instrument-related hazards (e.g., energy hazards).

B.3 Risk estimation

In estimating the risk for each hazard, the following aspects should be taken into account:

- extent of reliance on the analytical result (contribution to the medical decision);
- plausibility checks;
- availability and use of controls;
- quality assurance measures/techniques applied in medical laboratories;
- detectability of deficiencies/errors;
- situations of use (e.g., emergency cases);
- professional use/non-professional use;
- method of presentation of information.

Annex C

(informative)

Guidance on risk analysis procedure for toxicological hazards

C.1 General

This annex provides guidance on the application of risk analysis, with respect to toxicological hazards. Toxicological hazards are due to chemical constituents causing biological harm. ISO 10993-1 sets out the general principles for the biological evaluation of materials/medical devices.

Efforts should be made to avoid unnecessary testing using animals. Attention is drawn to ISO 10993-2 on animal welfare requirements, and to relevant national or regional regulations which may indicate that tests should be omitted if the omission can be scientifically justified.

C.2 Estimation of toxicological risks

C.2.1 Factors to be taken into account

The toxicological risk analysis should take account of

- the chemical nature of the materials,
- prior use of the materials, and
- biological safety test data.

The amount of data required and the depth of the investigation will vary with the intended use/intended purpose and are dependent upon the nature and duration of patient contact. Data requirements are usually less stringent for packaging materials, medical devices contacting intact skin, and any component of a medical device that does not come into direct contact with body tissues, infusible liquids, mucous membranes, or compromised skin.

Current knowledge of the material/medical device provided by scientific literature, previous clinical experience, and other relevant data should be reviewed to establish any need for additional data. In some cases, it can become necessary to obtain formulation data, residue data (e.g., from sterilization processes, monomers), biological test data, etc.

C.2.2 Chemical nature of the materials

Information characterizing the chemical identity and biological response of materials is useful in assessing a medical device for its intended use/intended purpose. Some factors that can affect the biocompatibility of the material include:

- the identity, concentration, availability, and toxicity of all constituents (e.g., additives, processing aids, monomers, catalysts, reaction products), and
- the influence of biodegradation and corrosion on the material.

Where reactive or hazardous ingredients have been used in, or can be formed by, the production, processing, storage or degradation of a material, the possibility of exposure to residues should be considered. Information on residue concentration and/or leaching can be necessary. This can take the form of experimental data or information on the chemistry of the materials involved.

Where the necessary data (e.g., complete formulation data) are not available to a manufacturer because of confidentiality, verification should be obtained that an assessment has been carried out of the suitability of the material for use in the proposed application.

C.2.3 Prior use

Available information on previous uses of each material or intended additive and on any adverse reactions encountered should be reviewed. However, the previous use of an ingredient or material does not necessarily assure its suitability in similar applications. Account should be taken of the intended use/intended purpose, the concentration of the ingredients, and current toxicological information.

C.2.4. Biological safety test data

ISO 10993-1 gives guidance on which tests in the ISO 10993 series should be considered for a particular application. The need for testing should be reviewed on a case-by-case basis in the light of existing data, so that unnecessary testing is avoided.

Annex D

(informative)

Examples of possible hazards and contributing factors associated with medical devices

D.1 General

This annex provides a non-exhaustive list of possible hazards together with contributing factors which may be associated with different medical devices. This list may be used to aid in the identification of hazards associated with a particular medical device.

D.2 Energy hazards and contributory factors

These include

- electricity,
- heat,
- mechanical force,
- ionizing radiation,
- non-ionizing radiation,
- moving parts,
- unintended motion,
- suspended masses,
- failure of patient-support device,
- pressure (e.g., vessel rupture),
- acoustic pressure,
- vibration,
- magnetic fields (e.g., MRI).

D.3 Biological hazards and contributory factors

These include

- bio-contamination,
- bio-incompatibility,
- incorrect formulation (chemical composition),
- toxicity,
- allergenicity,
- mutagenicity,
- oncogenicity,
- teratogenicity,
- carcinogenicity,
- re- and/or cross-infection,

- pyrogenicity,
- inability to maintain hygienic safety,
- degradation.

D.4 Environmental hazards and contributory factors

These include

- electromagnetic fields,
- susceptibility to electromagnetic interference,
- emissions of electromagnetic interference,
- inadequate supply of power,
- inadequate supply of coolant,
- storage or operation outside prescribed environmental conditions,
- incompatibility with other devices with which it is intended to be used,
- accidental mechanical damage,
- contamination due to waste products and/or medical device disposal.

D.5 Hazards resulting from incorrect output of energy and substances

These include

- electricity,
- radiation,
- volume,
- pressure,
- supply of medical gases,
- supply of anaesthetic agents.

D.6 Hazards related to the use of the medical device and contributory factors

These include

- inadequate labeling,
- inadequate operating instructions, such as
 - inadequate specification of accessories to be used with the medical device,
 - inadequate specification of pre-use checks,
 - over-complicated operating instructions,
 - inadequate specification of service and maintenance,
- use by unskilled/untrained personnel,
- reasonably foreseeable misuse,
- insufficient warning of side effects,
- inadequate warning of hazards likely with re-use of single-use medical devices,
- incorrect measurement and other metrological aspects,
- incompatibility with consumables/accessories/other medical devices,

- sharp edges or points.

D.7 Inappropriate, inadequate, or over-complicated user interface (man/machine communication)

These include

- mistakes and judgment errors,
- lapses and cognitive recall errors,
- slips and blunders (mental or physical),
- violation or abbreviation of instructions, procedures, etc.,
- complex or confusing control system,
- ambiguous or unclear device state,
- ambiguous or unclear presentation of settings, measurements, or other information,
- misrepresentation of results,
- insufficient visibility, audibility, or tactility,
- poor mapping of controls to action, or of displayed information to actual state,
- controversial modes or mappings as compared to existing equipment.

D.8 Hazards arising from functional failure, maintenance, aging, and contributory factors

These include

- erroneous data transfer,
- lack of, or inadequate specification for, maintenance including inadequate specification of post-maintenance functional checks,
- inadequate maintenance,
- lack of adequate determination of the end of life of the medical device,
- loss of electrical/mechanical integrity,
- inadequate packaging (contamination and/or deterioration of the medical device),
- re-use and/or improper re-use,
- deterioration in function (e.g., gradual occlusion of fluid/gas path, or change in resistance to flow, electrical conductivity) as a result of repeated use.

Annex E

(informative)

Risk concepts applied to medical devices

E.1 Risk estimation

Various methods can be used to estimate risk. While this International Standard does not require that a particular method be used, it does require that risk estimation is carried out (see 4.4). Quantitative risk estimation is possible when suitable data are available. Methods for quantitative risk estimation could merely include the adaptation of a qualitative method, or an alternative approach might be appropriate.

A risk chart such as Figure E.1 can be used as part of a qualitative method to define risk. Figure E.1 is an example of a risk chart and is included only to show the method. This does not imply that it has general application to medical devices. If a risk chart approach is used for estimating risk, the particular risk chart and the interpretation used should be justified for that application.

The concept of risk is the combination of the following two components:

- the probability of occurrence of harm, that is, how often the harm may occur;
- the consequences of that harm, that is, how severe it might be.

Risk estimation should examine the initiating events or circumstances, the sequence of events that are of concern, any mitigating features, and the nature and frequency of the possible deleterious consequences of the identified hazards. Risk should be expressed in terms that facilitate risk control decision making. In order to analyze risks, their components, i.e., probability and severity, should be analyzed separately.

E.2 Probability

E.2.1 Probability estimation

In appropriate situations where sufficient data are available, a quantitative categorization of probability levels is to be preferred. If this is not possible, the manufacturer should give a qualitative description. A qualitatively good description is preferable to quantitative inaccuracy. For a qualitative categorization of probability levels, the manufacturer can use descriptors appropriate for the medical device. The concept is in reality a continuum, however in practice a number of discrete levels can be used. In this case, the manufacturer decides how many categories are needed and how they are to be defined. The levels can be descriptive (e.g., incredible, improbable, remote, occasional, probable, frequent) or symbolic (P1, P2, etc.).

Probability estimation examines the initiating events or circumstances and the sequence of events that are of concern. This includes answering the following questions.

- Does the hazard occur in the absence of a failure?
- Does the hazard occur in a failure mode?
- Does the hazard occur only in a multiple-fault condition?

The probability of each undesired event occurring is identified at the hazard-identification stage. Three approaches are commonly employed to estimate probabilities, as follows:

- use of relevant historical data,
- prediction of probabilities using analytical or simulation techniques,
- use of expert judgment.

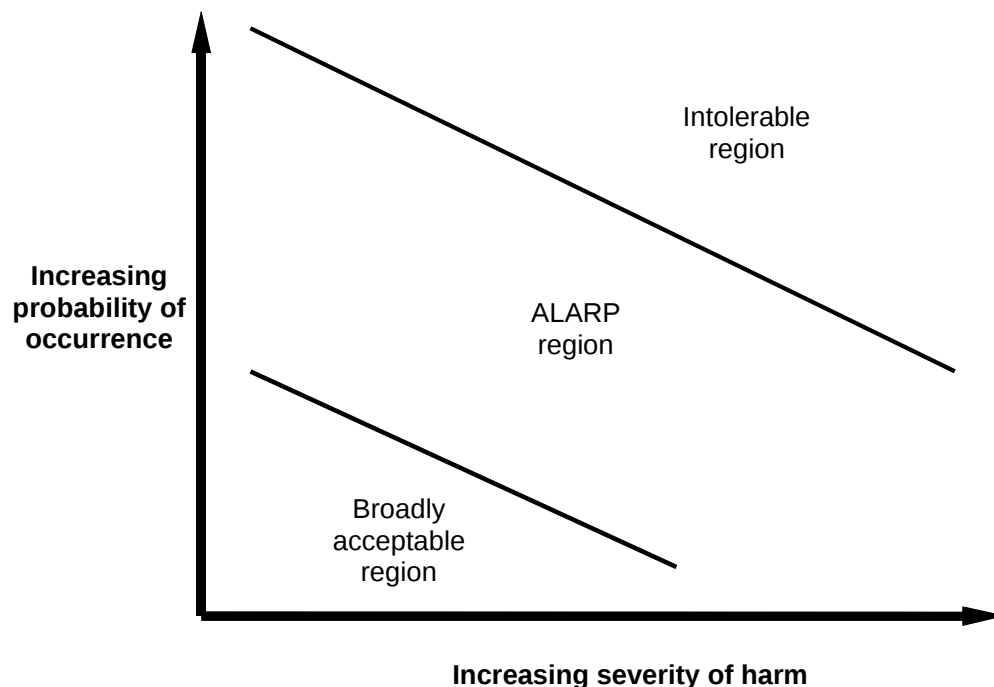


Figure E.1—Example of a three-region risk chart

All these approaches can be used individually or jointly. The first two approaches are complementary; each has strength where the other has weaknesses. Wherever possible, both should be used. In this way, they can be used as independent checks on each other, and this might serve to increase confidence in the results. When these cannot be used or are not sufficient, it might be necessary to rely on expert judgment.

Some hazards occur because of systematic rather than random failures. For example, hazards derived from software failures are due to systematic failures. For a discussion on how to address systematic failures, see E.4.3.

E.2.2 Severity levels

For a qualitative categorization of the levels of severity, the manufacturer should use descriptors appropriate for the medical device. The concept is in reality a continuum, however in practice a number of discrete levels can be used. In this case, the manufacturer decides how many categories are needed and how they are to be defined. The levels may be descriptive (e.g., negligible, marginal, critical, serious, catastrophic) or symbolic (S1, S2, etc.).

These levels will need to be customized by the manufacturer for a particular medical device considering both short-term and long-term effects.

E.3 Risk acceptability

E.3.1 General

This International Standard does not specify acceptable risk. Methods of determining acceptable risk include the following:

- using applicable standards that specify requirements which, if implemented, will indicate achievement of acceptability concerning particular kinds of medical devices or particular risks;
- following appropriate guidance, for example, that obtained by using the single-fault philosophy (for details, see 9.10 of IEC/TR 60513:1994);
- comparing levels of risk evident from medical devices already in use.

Risk should only be accepted in a particular situation if it is outweighed by benefits.

Risks can be categorized into the following three regions:

- broadly acceptable region;

- ALARP (As Low As Reasonably Practicable) region;
- intolerable region.

A three-region concept of risk is illustrated in Figure E.1. These regions will need to be customized for a particular medical device.

Examples of the use of numerical probability and severity estimates can be found in some of the standards listed in the bibliography. Users of this International Standard are urged to define probability and severity categories applicable to their own particular application.

E.3.2 Broadly acceptable region

In some cases, a risk is so low that it is negligible in comparison with other risks and in view of the benefit of using the medical device. In such cases, the risk is acceptable, and risk control need not be actively pursued.

E.3.3 ALARP region

It might be thought that any risk associated with a medical device would be acceptable if the patient's prognosis were improved. This cannot be used as a rationale for the acceptance of unnecessary risk. Any risk should be reduced to the lowest level practicable, bearing in mind the benefits of accepting the risk and the practicability of further reduction.

Practicability refers to the ability of a manufacturer to reduce the risk. Practicability has two components:

- a) technical practicability, and
- b) economic practicability.

Technical practicability refers to the ability to reduce the risk regardless of cost. Economic practicability refers to the ability to reduce the risk without making the provision of the medical device an unsound economic proposition. Cost and availability implications are considered in deciding what is practicable to the extent that these impact upon the preservation, promotion, or improvement of human health.

Major risks should normally be reduced even at considerable cost. Near the broadly acceptable region, a balance between risk and benefit may suffice.

E.3.4 Intolerable region

Some risks, if they cannot be reduced, may always be judged intolerable.

E.3.5 Risk-acceptability decisions

There is an important distinction to be made between risks that are so low that there is no need to consider them and risks which are greater than that but which we are prepared to live with because of the associated benefits and the impracticality of reducing the risks. When a hazard has been identified and the risk estimated, the first question to be asked is whether the risk is already so low that there is no need to consider it and therefore no need to progress to risk reduction. This decision is made once for each hazard.

If the decision at the first stage is that the risk is not so low that there is no need to consider it, the next stage is to progress to risk reduction. Risk reduction might or might not be practicable, but it should be considered. The possible outcomes of this second stage are as follows:

- that one or more risk-reduction measures bring the risk down to a level where it is not necessary to consider it further; or
- that, whether or not some risk reduction is possible, reducing the risk down to the "no need to consider it" level is not practicable.

In the latter case, the risk should be reduced to a level as low as reasonably practicable (ALARP), and then the risk and benefit should be compared. If the risk is outweighed by the benefit, then the risk may be accepted. If the risk is not outweighed by the benefit, then it is unacceptable, and the design should be abandoned.

Finally, once all risks have been found to be acceptable, the overall residual risk is evaluated to assure that the risk/benefit balance is still maintained.

Thus, there are three decision points in the process, where different questions are asked about the acceptability of risks:

- a) Whether the risk is so low that there is no need to consider it?
- b) Whether there is no longer any reason to consider the risk, or the risk is as low as is reasonably practicable and outweighed by the benefit?
- c) Whether the overall balance of all the risks with all the benefits is acceptable?

E.4 Cause of failure

E.4.1 Failure types

A hazardous situation can result from the failure of a system. There are two possible types of failure:

- random failures, and
- systematic failures.

E.4.2 Random failure

For many events, a statistical probability of failure can be assigned (e.g., the probability of failure of an assembly is often estimated from the failure probabilities of the components which make up the assembly). In this case, a numerical value can be given for the probability of failure. An essential presumption is that the failures are random in nature. Hardware is assumed to fail either in a random or in a systematic manner. Software is assumed to fail in a systematic manner.

E.4.3 Systematic failure

Systematic failures are due to errors (including errors of commission and omission) in any activity which, under some particular combination of inputs or environmental conditions, will permit a failure.

The error leading to systematic failures can occur in both hardware and software and can be introduced at any time during a medical device's development, manufacture, or maintenance. Examples of a systematic failure are as follows:

- a) An incorrectly rated fuse fails to prevent a hazardous situation. The fuse rating might have been incorrectly specified, incorrectly fitted during manufacture, or incorrectly replaced during repair.
- b) The use of incorrect material in a joint replacement results in excessive wear and premature failure of a hip implant. The incorrect material may have been incorrectly specified or incorrectly used during manufacture (e.g., the incorrect material is ordered from the supplier).
- c) A software database does not provide for the condition of full database. If the database is full, it is not clear what the software will do. A possible consequence is that the system will delete existing records to make room for new ones.

The accurate estimation of systematic failure rates is difficult. This occurs primarily for the two following reasons:

- a) Systematic failure rates are laborious and expensive to measure. Achieving a reasonable level of confidence in the result will not be possible without a long history of measuring failure rates.
- b) Consensus does not exist for a method of estimating systematic failure rates quantitatively.

In cases where an appropriate level of confidence cannot be established for the estimation of systematic failures, the risk should be managed based on the severity of the harm resulting from the hazard. Initially, the risk estimation for systematic faults should be based on the presumption that systematic failure will occur at an unacceptable rate.

There is a relationship between the quality of the development processes used and the possibility of a systematic fault being introduced or remaining undetected. It is often appropriate to determine the required quality of the development process by taking account of the severity of the consequence of the systematic faults and the effect of external risk-control measures. The worse the consequence and the less the effect of external risk-control measures, the higher the required quality of the development process.

Annex F

(informative)

Information on risk analysis techniques

F.1 General

This annex provides guidance on some available techniques for probabilistic safety analysis that can be used under 4.3. These techniques are complementary and it might be necessary to use more than one of them. The basic principle is that the possible consequences of a postulated event are analyzed step by step. For further details, see also IEC 60300-3-9.

F.2 Failure Mode and Effect Analysis (FMEA)

FMEA is primarily a qualitative technique by which the consequences of an individual component fault mode are systematically identified and evaluated. It is an inductive technique using the question “What happens to the output if . . . ?” Components are analyzed one at a time, thus generally looking at a single-fault condition. This is done in a “bottom-up” mode, i.e., following the process to the next higher functional system level.

FMEA can be extended to incorporate an investigation of the degree of severity of the consequences, their respective probabilities of occurrence and their detectability, and can become a so-called Failure Mode Effect and Criticality Analysis (FMECA). In order to perform such an analysis, the construction of the medical device should be known in some detail.

FMEA can also be a useful technique to deal with human error. It can also be used to identify hazards and thus provide valuable input to a Fault Tree Analysis (FTA).

Disadvantages of this technique can arise from difficulties in dealing with redundancies and the incorporation of repair or preventive maintenance actions, as well as its restriction on single-fault conditions.

See IEC 60812 for more information on the procedures for failure mode and effects analysis.

F.3 Fault Tree Analysis (FTA)

FTA is primarily a means of analyzing hazards identified by other techniques and starts from a postulated undesired consequence, also called a “top event.” In a deductive manner, starting with the top event, the possible causes or fault modes of the next lower functional system level causing the undesired consequence are identified. Following stepwise identification of undesirable system operation to successively lower system levels will lead to the desired system level, which is usually the component fault mode. This will reveal the sequences most likely to lead to the postulated consequence. It has therefore proved to be useful for forensic purposes.

The results are represented pictorially in the form of a tree of fault modes. At each level in the tree, combinations of fault modes are described with logical operators (AND, OR, etc.). The fault modes identified in the tree may be events that are associated with hardware failures, human errors, or any other pertinent event which leads to the undesired event. They are not limited to the single-fault condition.

FTA allows a systematic approach which, at the same time, is sufficiently flexible to allow analysis of a variety of factors, including human interactions. FTA is primarily used in risk analysis as a tool to provide an estimate of failure probabilities. The pictorial representation leads to an easy understanding of the system behavior and the factors included, but, as the trees become large, processing of fault trees may require computer systems. This feature makes the verification of the fault tree difficult.

See IEC 61025 for more information on the procedures for fault tree analysis.

F.4 Hazard and Operability Study (HAZOP)

HAZOP is similar to an FMEA. HAZOP is based on a theory that assumes accidents are caused by deviations from the design or operating intentions. It is a systematic technique for identifying hazards and operability problems. It was originally developed for use in the chemical process industry. While the use of HAZOP studies in the chemical industry focuses on deviations from design intent, there are alternative applications for a medical device developer. A HAZOP can be applied to the operation of the medical device (e.g., to the existing methods/processes used for the diagnosis, treatment, or alleviation of disease as the “design intent”), or to a process used in the manufacture or maintenance of the medical device (e.g., sterilization) that may have significant impact on the function of the medical device. Two particular features of a HAZOP are as follows:

- a) it uses a team of people with expertise covering the design of the medical device and its application; and
- b) guide words (NONE, PART OF, etc.) are used to help identify deviations from normal use.

The objectives of the technique are

- to produce a full description of the medical device and how it is intended to be used,
- to review systematically every part of the intended use/intended purpose to discover how deviations from the normal operating conditions and the intended design can occur,
- to identify the consequences of such deviations and to decide whether these consequences can lead to hazards or operability problems.

When applied to the processes used to manufacture a medical device, the last objective is particularly useful in those cases where the medical device characteristics depend upon the manufacturing process.

Annex G (informative)

Other standards that contain information related to the elements of risk management described in this International Standard

Table G.1—Quality management elements that may be related to the elements of risk management

Overview of the risk management process		Subclauses of ISO 13485:1996 ^a																			
		4.1	4.2 (see note 1)	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12	4.13	4.14	4.15	4.16 (see note 2)	4.17	4.18	4.19	4.20
General requirements																					
Risk analysis	Scope definition																				
	Hazard identification																				
	Risk estimation																				
Risk evaluation																					
Risk control	Analysis of options																				
	Decision making																				
	Implementation																				
Post-production information																					

NOTE 1—Risk management can be part of a quality management system.

NOTE 2—The risk management file can include quality records.

^a Shaded areas indicate the parts of the risk management process which might be related to this International Standard.

Table G.2—Other International Standards that may be related to the elements of risk management

Overview of the risk management process		Applicable standards ^a										
		ISO 9001	ISO 9000-3	ISO 10993-1	ISO 13485	ISO 14969	IEC 60300-3-9	IEC/TR 60513	IEC 60601-1-4	IEC 60812	IEC 61025	EN 12442-1
Risk analysis	Scope definition											
	Hazard identification											
	Risk estimation											
Risk evaluation												
Risk control	Analysis of options											
	Decision making											
	Implementation											
Post-production information												

^a Shaded areas indicate the parts of the risk management process which might be related to these International Standards.

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- [1] ISO/IEC Guide 2:1996, *Standardization and related activities—General vocabulary*.
- [2] ISO/IEC Guide 51:1999, *Safety aspects—Guidelines for the inclusion in standards*.
- [3] ISO 8402:1994¹⁾, *Quality management and quality assurance—Vocabulary*.
- [4] ISO 9000-3:1991, *Quality management and quality assurance standards—Part 3: Guidelines for the application of ISO 9001 to the development, supply and maintenance of software*.
- [5] ISO 9001:—²⁾, *Quality management systems—Requirements*.
- [6] ISO 10993-1, *Biological evaluation of medical devices—Part 1: Evaluation and testing*.
- [7] ISO 10993-2, *Biological evaluation of medical devices—Part 2: Animal welfare requirements*.
- [8] ISO 10993-17, *Biological evaluation of medical devices—Part 17: Establishment of allowable limits for leachable substances using health-based risk assessment*.
- [9] ISO 13485, *Quality systems—Medical devices—Particular requirements for the application of ISO 9001*.
- [10] ISO 13488, *Quality systems—Medical devices—Particular requirements for the application of ISO 9002*.
- [11] ISO 14969, *Quality systems—Medical devices—Guidance on the application of ISO 13485 and ISO 13488*.
- [12] ISO 15189, *Quality management in the medical laboratory*.
- [13] IEC 60300-3-9, *Dependability management—Part 3: Application guide—Section 9: Risk analysis of technological systems*.
- [14] IEC/TR 60513, *Fundamental aspects of safety standards for medical electrical equipment*.
- [15] IEC 60601-1:1988, *Medical electrical equipment—Part 1: General requirements for safety*.
- [16] IEC 60601-1-4, *Medical electrical equipment—Part 1: General requirements for safety—4: Collateral standard: Programmable electrical medical systems*.
- [17] IEC 60812, *Analysis techniques for system reliability—Procedures for failure mode and effects analysis (FMEA)*.
- [18] IEC 61025, *Fault tree analysis (FTA)*.
- [19] IEC 61882, *Guide for hazard and operability studies (HAZOP studies)*.
- [20] EN 12442-1, *Animal tissues and their derivatives utilized in the manufacture of medical devices—Part 1: Analysis and management of risk*.
- [21] 90/285/EEC, *Council Directive of 20 June 1990 on the approximation of the laws of the Member States relating to active implantable medical devices (90/385/EEC) as amended by Council Directive 93/42/EEC of 14 June 1993 concerning medical devices and Council Directive 93/68/EEC of 22 July 1993*.
- [22] 93/42/EEC, *Council Directive 93/42/EEC of 14 June 1993 concerning medical devices as amended by Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro diagnostic medical devices*.
- [23] 98/79/EC, *Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro diagnostic medical devices*.

1) This is under revision and will be reissued as ISO 9000:2000.

2) To be published. (Revision of ISO 9001:1994, ISO 9002:1994, and ISO 9003:1994.)

Medical devices—Application of risk management to medical devices

Amendment 1: Rationale for requirements

Approved 6 June 2003 by
Association for the Advancement of Medical Instrumentation

Approved 18 June 2003 by
American National Standards Institute

AAMI Standard

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Glossary of equivalent standards

International standards adopted in the United States may include normative references to other international standards. For each international standard that has been adopted by AAMI (and ANSI), the table below gives the corresponding U.S. designation and level of equivalency to the international standard. (Note: Documents are sorted by international designation.)

Other normatively referenced international standards may be under consideration for U.S. adoption by AAMI; therefore, this list should not be considered exhaustive.

International designation	U.S. designation	Equivalency
IEC 60601-1-2:2001	ANSI/AAMI/IEC 60601-1-2:2001	Identical
IEC 60601-2-21:1994 and Amendment 1:1996	ANSI/AAMI/IEC 60601-2-21 & Amendment 1:2000 (consolidated texts)	Identical
IEC 60601-2-24:1998	ANSI/AAMI ID26:1998	Major technical variations
ISO 5840:1996	ANSI/AAMI/ISO 5840:1996	Identical
ISO 7198:1998	ANSI/AAMI/ISO 7198:1998/2001	Identical
ISO 7199:1996	ANSI/AAMI/ISO 7199:1996/(R)2002	Identical
ISO 10993-1:1997	ANSI/AAMI/ISO 10993-1:1997	Identical
ISO 10993-2:1992	ANSI/AAMI/ISO 10993-2:1993/(R)2001	Identical
ISO 10993-3:1992	ANSI/AAMI/ISO 10993-3:1993	Identical
ISO 10993-4:2002	ANSI/AAMI/ISO 10993-4:2002	Identical
ISO 10993-5:1999	ANSI/AAMI/ISO 10993-5:1999	Identical
ISO 10993-6:1994	ANSI/AAMI/ISO 10993-6:1995/(R)2001	Identical
ISO 10993-7:1995	ANSI/AAMI/ISO 10993-7:1995/(R)2001	Identical
ISO 10993-8:2000	ANSI/AAMI/ISO 10993-8:2000	Identical
ISO 10993-9:1999	ANSI/AAMI/ISO 10993-9:1999	Identical
ISO 10993-10:2002	ANSI/AAMI BE78:2002	Minor technical variations
ISO 10993-11:1993	ANSI/AAMI 10993-11:1993	Minor technical variations
ISO 10993-12:2002	ANSI/AAMI/ISO 10993-12:2002	Identical
ISO 10993-13:1998	ANSI/AAMI/ISO 10993-13:1999	Identical
ISO 10993-14:2001	ANSI/AAMI/ISO 10993-14:2001	Identical
ISO 10993-15:2000	ANSI/AAMI/ISO 10993-15:2000	Identical
ISO 10993-16:1997	ANSI/AAMI/ISO 10993-16:1997/(R)2003	Identical
ISO 10993-17:2002	ANSI/AAMI/ISO 10993-17:2002	Identical
ISO 11134:1994	ANSI/AAMI/ISO 11134:1993	Identical
ISO 11135:1994	ANSI/AAMI/ISO 11135:1994	Identical
ISO 11137:1995 and Amdt 1:2001	ANSI/AAMI/ISO 11137:1994 and A1:2002	Identical
ISO 11138-1:1994	ANSI/AAMI ST59:1999	Major technical variations

International designation	U.S. designation	Equivalency
ISO 11138-2:1994	ANSI/AAMI ST21:1999	Major technical variations
ISO 11138-3:1995	ANSI/AAMI ST19:1999	Major technical variations
ISO TS 11139:2001	ANSI/AAMI/ISO 11139:2002	Identical
ISO 11140-1:1995 and Technical Corrigendum 1:1998	ANSI/AAMI ST60:1996	Major technical variations
ISO 11607:2003	ANSI/AAMI/ISO 11607:2000	Identical
ISO 11737-1:1995	ANSI/AAMI/ISO 11737-1:1995	Identical
ISO 11737-2:1998	ANSI/AAMI/ISO 11737-2:1998	Identical
ISO TR 13409:1996	AAMI/ISO TIR13409:1996	Identical
ISO 13485:2003	ANSI/AAMI/ISO 13485:2003	Identical
ISO 13488:1996	ANSI/AAMI/ISO 13488:1996	Identical
ISO 14155-1:2003	ANSI/AAMI/ISO 14155-1:2003	Identical
ISO 14155-2:2003	ANSI/AAMI/ISO 14155-2:2003	Identical
ISO 14160:1998	ANSI/AAMI/ISO 14160:1998	Identical
ISO 14161: 2000	ANSI/AAMI/ISO 14161:2000	Identical
ISO 14937:2000	ANSI/AAMI/ISO 14937:2000	Identical
ISO 14969:1999	ANSI/AAMI/ISO 14969:1999	Identical
ISO 14971:2000 and A1:2003	ANSI/AAMI/ISO 14971:2000 and A1:2003	Identical
ISO 15223:2000	ANSI/AAMI/ISO 15223:2000	Identical
ISO 15223/A1:2002	ANSI/AAMI/ISO 15223:2000/A1:2001	Identical
ISO 15225:2000	ANSI/AAMI/ISO 15225:2000	Identical
ISO 15674:2001	ANSI/AAMI/ISO 15674:2001	Identical
ISO 15675:2001	ANSI/AAMI/ISO 15675:2001	Identical
ISO TS 15843:2000	ANSI/AAMI/ISO TIR15843:2000	Identical
ISO TR 15844:1998	AAMI/ISO TIR15844:1998	Identical
ISO TR 16142:1999	ANSI/AAMI/ISO TIR16142:2000	Identical
ISO 25539-1:2003	ANSI/AAMI/ISO 25539-1:2003	Identical

Committee representation

Association for the Advancement of Medical Instrumentation

Quality Management and Corresponding General Aspects for Medical Devices Committee

The adoption of ISO 14971:2000/Amendment 1:2003 as an amendment to the corresponding American National Standard (ANSI/AAMI/ISO 14971:2000) was initiated by the AAMI Quality Management and Corresponding General Aspects for Medical Devices Committee, which also functions as a U.S. Technical Advisory Group to the relevant work in the International Organization for Standardization (ISO). U.S. representatives from the AAMI Application of Risk Management to Medical Devices Working Group (U.S. Sub-TAG for ISO/IEC JWG1), chaired by Harvey Rudolph, PhD, of Underwriters Laboratories, Inc. and Edwin Bills of Hill-Rom Company played an active part in developing the ISO standard.

At the time this document was published, the **AAMI Quality Management and Corresponding General Aspects for Medical Devices Committee** had the following members:

Cochair: Charles B. Sidebottom, PE
Members: Leighton W. Hansel, Abbott Laboratories
Edward R. Kimmelman, BME, JD, Roche Diagnostics Corp.
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NOTE—Participation by federal agency representatives in the development of this standard does not constitute endorsement by the federal government or any of its agencies.

Background of ANSI/AAMI adoption of ISO 14971:2000/Amendment 1:2003

As indicated in the foreword to the main body of this document (page ix), the International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. The United States is one of the ISO members that took an active role in the development of this standard.

ISO 14971:2000/Amendment 1:2003 was developed by Technical Committee ISO/TC 210, Quality management and corresponding general aspects for medical devices, to provide the reasoning for establishing the various requirements contained in ISO 14971:2000.

U.S. participation in this ISO TC is organized through the U.S. Technical Advisory Group for ISO/TC 210, administered by the Association for the Advancement of Medical Instrumentation on behalf of the American National Standards Institute. The U.S. made a considerable contribution to this International Standard Amendment.

AAMI encourages its committees to harmonize their work with International Standards in the area of quality management and corresponding general aspects for medical devices. Upon review of ISO 14971/Amendment 1, the Quality Management and Corresponding General Aspects for Medical Devices Committee and the AAMI Application of Risk Management to Medical Devices Working Group decided to adopt Amendment 1, verbatim, as an amendment to ANSI/AAMI/ISO 14971:2000.

AAMI and ANSI procedures require that standards be reviewed and, if necessary, revised every five years to reflect technological advances that may have occurred since publication.

AAMI (and ANSI) have adopted other ISO standards. See the Glossary of Equivalent Standards for a list of ISO standards adopted by AAMI, which gives the corresponding U.S. designation and the level of equivalency with the ISO standard.

The concepts incorporated in this standard should not be considered inflexible or static. This standard, like any other, must be reviewed and updated periodically to assimilate progressive technological developments. To remain relevant, it must be modified as technological advances are made and as new data comes to light.

Suggestions for improving this standard are invited. Comments and suggested revisions should be sent to Standards Department, AAMI, 1110 N. Glebe Road, Suite 220, Arlington, VA 22201-4795.

NOTE—Beginning with the ISO foreword on page ix, this American National Standard Amendment is identical to ISO 14971:2000/Amendment 1:2003.

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to ISO 14971:2000 was prepared by Technical Committee ISO/TC 210, *Quality management and corresponding general aspects for medical devices*, and Subcommittee IEC/SC 62A, *Common aspects of electrical equipment used in medical practice*.

At the time of publication of ISO 14971:2000, it was anticipated that maintenance of the standard would be required within a few years. IEC/SC 62A has already anticipated that a revision may be needed in about 2005. In anticipation of the maintenance process, ISO/TC 210-IEC/SC 62A Joint Working Group 1, *Application of risk management to medical devices*, developed this Amendment to document its reasoning for establishing the various requirements contained in ISO 14971. Those who make future revisions to the standard can use this Amendment, along with experience gained in the use of the standard, to make the standard more useful to manufacturers, regulatory bodies, and health care providers.

The material in this Amendment is purely informative. It does not alter in any way the requirements of ISO 14971 or modify any of the other informative material.

Introduction

A standard for the application of risk management to medical devices became important largely because of the increasing recognition by regulators that the manufacturer should apply risk management to medical devices. No medical device risk management standard existed, and ISO 14971 was written to fill that gap. ISO/TC 210 Working Group 4 was formed to develop the new standard. Almost simultaneously, drafters of the third edition of IEC 60601-1 planned to have risk management included in the standard then under development. They saw the need for a separate risk management activity and formed Working Group 15 of IEC/SC 62A. Recognizing that the efforts of these two working groups overlapped, IEC and ISO formed the Joint Working Group 1 (JWG 1) on Risk Management combining the membership of both working groups. This collaboration resulted in the publication of ISO 14971 with both an ISO and an IEC logo. The dual logo signifies that both ISO and IEC recognize ISO 14971 as the International Standard covering the application of risk management to medical devices.

When JWG 1 started its discussions on the international risk management standard, there was no satisfactory standard in place to address risk management for medical devices. Crucial features of risk management needed to be addressed such as the process of risk evaluation, as well as the balancing of risks and benefits for medical devices. Manufacturers, regulatory bodies, and health care providers had recognized that “absolute safety” in medical devices was not achievable. In addition, the risks that derive from the increasing diversity of medical devices and their applications cannot be completely addressed through product safety standards. The recognition of these facts and the consequent need to manage risks from medical devices throughout their life cycle led to the decision to develop ISO 14971.

The JWG 1's original plan was to write ISO 14971 in several parts, each dealing with a specific aspect of risk management. ISO 14971-1:1998, covering risk analysis, was intended as the first part of an overall risk management standard. Later, the JWG 1 decided that it was better to develop a single document that would include all aspects of risk management. The main reason for this was that it was apparent that risk management would be mandated by several regulatory regimes in the world, including Europe. It was therefore no longer useful or necessary to have a separate standard on risk analysis available. Also, making one risk management standard instead of having several parts would much better show the coherence between the several aspects of risk management.

In this Amendment, the numbering parallels the numbering of the clauses and subclauses of ISO 14971:2000.

Medical devices—Application of risk management to medical devices

Amendment 1: Rationale for requirements

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Add the following annex before the Bibliography.

Annex H (informative)

Rationale for requirements

H.1 Rationale for Clause 1, Scope

As explained in the Introduction, a risk management standard applying to all medical devices is required. Risks exist throughout the product life cycle, and risks that become apparent at one point in the life cycle may be managed by action taken at a completely different point in the life cycle. For this reason, this International Standard is intended to be a complete life cycle standard. This means that it instructs manufacturers to apply risk management principles to a medical device from its initial conception until its ultimate decommissioning and disposal.

This International Standard is not intended to be applicable to clinical decision making. The decision to embark upon a clinical procedure utilizing a medical device requires the residual risks to be balanced against the anticipated benefits of the procedure. Such judgements should take into account the intended use/intended purpose, performance, and risks associated with the medical device as well as the risks and benefits associated with the clinical procedure or the circumstances of use. Some of these judgements may be made only by a qualified health care professional with knowledge of the state of health of an individual patient and the patient's own opinion.

Although there has been significant debate over what constitutes an acceptable level of risk, this International Standard does not specify acceptability levels. Specifying a single level for acceptable risk would be inappropriate because

— the wide variety of devices and situations covered by this International Standard would make a single level meaningless, and

— local laws, customs, and values are more appropriate for defining risk acceptability for a particular culture or region of the world.

Because not all countries require a quality system for medical device manufacturers, a quality system is not required in this International Standard. However, a quality system is extremely helpful in managing risks properly. Because of this and because most medical device manufacturers do employ a quality system, this International Standard is constructed so that it can easily be incorporated into the quality system that they use. The relationship with ISO 13485:1996 is shown in Table G.2 in Annex G.

H.2 Rationale for Clause 2, Terms and definitions

It was not intended to invent a host of new and possibly unfamiliar terms and so this International Standard is intentionally built upon the wealth of risk management information both in standards and in the literature. Existing definitions were used wherever possible. The primary sources for the definitions were ISO/IEC Guide 51:1999 and ISO 8402:1994¹⁾.

1) ISO 8402:1994 has been replaced by ISO 9000:2000. However, the definitions of terms such as "objective evidence" in ISO 14971:2000 were taken from ISO 8402:1994.

* Page 39 in the ISO version.

It was known that risk management would be made mandatory, either explicitly or implicitly, by the European Union (EU), the United States, and other countries and regions of the world. Therefore definitions were used that would be widely acceptable in a regulatory sense. For example, the term “manufacturer” (2.6) while based on the medical device directive in the EU, is consistent with the definition used in the United States. The term “medical device” (2.7) was taken from ISO 13485 where a similar consideration for local regulations had also been applied. The combined term “intended use/intended purpose” (2.5) was used because there was no consensus on which term to use. The Medical Device Directive uses “intended purpose,” whereas the United States regulations use “intended use.” Both terms have essentially the same definition. It was decided to use the combined term along with a definition that is similar to that used in both the EU and the United States.

Only three terms in this International Standard are not based on definitions in other standards. These are “risk control” (2.16), “risk management” (2.18), and “risk management file” (2.19). The definition for “risk control” was provided to be consistent with the definitions of “risk analysis” and “risk evaluation” given by ISO/IEC Guide 51. The definition for “risk management” emphasizes the use of a systematic approach and the need for management overview. The concept of a “risk management file” was originally expressed in IEC 60601-1-4, but the definition was changed because the definition in IEC 60601-1-4 refers to quality records, which need not exist for compliance with ISO 14971.

H.3 Rationale for Clause 3, General requirements for risk management

Although risk management activities are highly individual to the device being evaluated, there are basic elements that need to be included in the risk management process. This clause satisfies that need. This clause also allows for some differences in the requirements for meeting this standard, based on local differences in regulatory approaches.

H.3.1 National or regional regulatory requirements

Worldwide applicability of this International Standard is important despite differing regional regulatory requirements. This subclause was needed so that both Europe and the United States (as well as other countries and regions) could use this International Standard in their regulatory programs. In Europe, manufacturers do not need to have a certified quality system in place to meet the essential requirements necessary for applying a CE mark to their product. In the United States, a quality system is always required to market a device (unless the device is specifically exempted). Subclauses 3.3 and 3.4 closely follow quality system requirements. This subclause enables manufacturers to apply 3.3 and 3.4 in conjunction with a quality system, when required by their local regulatory authorities.

H.3.2 Risk management process

This subclause requires each manufacturer to establish a risk management process as part of the design of a medical device. This is required so that the manufacturer can systematically ensure that the required elements are in the process. Risk analysis, risk evaluation, and risk control are commonly recognized as essential parts of risk management. In addition to these elements, it was necessary to emphasize, however, that the risk management process does not end with the design and manufacturing of a medical device, but continues on into the post-production phase. Therefore, the gathering of post-production information was identified as a required part of the risk management process. When a manufacturer employs a quality system, the risk management process should be fully integrated into that quality system.

H.3.3 Management responsibilities

The commitment of a manufacturer's management is critical for an effective risk management process. These individuals should take responsibility for overall guidance of the risk management process. Therefore, this subclause was included to emphasize that role. In particular, the following was concluded.

- a) Because this International Standard does not define acceptable risk levels, the manufacturer has to decide what criteria to apply, taking account of relevant factors.
- b) In the absence of adequate resources, risk management activities would be less effective, even if complying with the letter of the other requirements of this International Standard.
- c) Risk management is a specialized discipline and requires the use of individuals trained in risk management techniques (see H.3.4).
- d) Risk management is an evolving process and periodic review of the risk management activities is needed to ascertain whether they are being carried out correctly, to rectify any weaknesses, to implement improvements, and to adapt to changes.

H.3.4 Qualification of personnel

It is essential to get qualified people to perform risk management tasks. Risk management processes require people who know

- how the device is constructed,
- how the device works,
- how the device is intended, or likely, to be used, and
- how to apply the risk management process.

In general, this will require several experts, each contributing their specialist knowledge. Records of the appropriate qualifications are required to provide objective evidence. For confidentiality reasons, this International Standard does not require these records to be kept in the risk management file.

H.3.5 Risk management plan

A risk management plan is required because

- an organized approach is essential for good risk management,
- the plan provides the roadmap for risk management, and
- the plan encourages objectivity and helps prevent essential elements being forgotten.

A plan is also beneficial for reuse of the process for subsequent risk management programs. Elements a) to e) are required for the following reasons.

- a) There are two distinct elements in the scope of the plan. The first identifies the intended medical device or accessory; the other identifies the phases of the life cycle covered by the plan. By defining the scope, it can be seen if any part of the device is not included and if parts of the life cycle have to be covered by another plan.
- b) Verification is an essential activity and is required by 6.3. Planning this activity helps ensure that essential resources are available when required. If verification is not planned, important parts of the verification could be neglected.
- c) The allocation of responsibilities is needed to ensure that no responsibility is omitted.
- d) This point is included as a generally recognized responsibility of management.
- e) The criteria for risk acceptability are fundamental to risk management and should be decided upon before risk analysis begins. This helps make the process in Clause 5 objective.

The requirement to keep a record of changes is to facilitate audit and review of the process.

H.3.6 Risk management file

This International Standard uses this term to signify where the manufacturer can locate or find the locations of all the records applicable to risk management. This facilitates the risk management and enables more efficient auditing to this International Standard.

H.4 Rationale for Clause 4, Risk analysis

ISO 14971-1:1998, *Medical devices—Risk management—Part 1: Application of risk analysis*, was used as the basis of this clause. ISO 14971-1 was the ISO version of EN 1441 on medical device risk analysis. EN 1441 was written under a mandate of the European Commission, and it gives the presumption of conformance with the requirements for risk analysis of the European medical device regulations.²⁾

In this and subsequent clauses of this International Standard, the requirements are keyed to the steps of the flow diagram in Figure 2. Figure 2 was provided to give the user an overview of the risk management process. Providing a key (in the form of step numbers) between the figure and the actual requirements in text would prove a useful aid. This is an expansion of the mechanism provided in ISO 14971-1. As indicated in Figure 2, the process needs to be

²⁾ EN 1441 was ratified on 13 September 1997 and its reference number published in the European Community's Official Journal of 9 May 1998.

iterative, covering each risk in turn, and returning to earlier steps if risk control measures introduce new hazards or if new information becomes available.

H.4.1 Risk analysis procedure

The risk analysis procedure is described in 4.2, 4.3, and 4.4.

A note was added on how to deal with the availability of a risk analysis for a similar medical device to inform users of this International Standard that when adequate information already exists it can and should be applied to save time, effort and other resources. Users of this International Standard need to be careful, however, to assess systematically their previous work for applicability to the current risk analysis.

Note that details required by a), b), and c) form the basic minimum data set for ensuring traceability and are important for management reviews and for subsequent audits. The requirement in a) also helps clarify what is in the scope of the analysis and verify completeness.

H.4.2 Intended use/intended purpose and identification of characteristics related to the safety of the medical device

This step forces the manufacturer to think about all the characteristics that could affect safety of the medical device. This analysis should include “reasonably foreseeable misuse.” Devices are frequently used in situations other than those intended by the manufacturer and in situations other than those foreseen when a device is first conceived. It is important that the manufacturer tries to look into the future to see the hazards due to potential uses of their device.

Annex A is intended to be helpful in describing the characteristics of the medical device and the environments in which it is used. It cannot be emphasized too strongly that this list is not exhaustive. Every manufacturer should be creative in determining the relevant safety characteristics for the medical device under investigation. The list in Annex A was originally taken from ISO 14971-1:1998, with some additions made as a result of comments on drafts of that standard. The list ought to stimulate thinking of “where can things go wrong?” Annex B on *in vitro* devices and Annex C on toxicological hazards have been taken from Annex A and Annex B, respectively, of ISO 14971-1:1998 with only minor changes.

H.4.3 Identification of known or foreseeable hazards

This step requires that the manufacturer be systematic in the identification of potential hazards. The manufacturer should list “known or foreseeable hazards” based upon the safety characteristics identified in 4.2. A risk can only be assessed and managed once a hazard has been identified. Listing the hazards allows this to be done systematically.

Annex D was provided to give examples of “possible hazards and contributing factors.” This terminology was used because it may not always be clear whether something is a “hazard” or a “contributing factor.” This is especially true when there is a sequence of events that in the end may lead to a hazardous situation. The manufacturer should recognize these sequences of events to address risk properly. Whether a specific element of this sequence is called a hazard or a contributing factor is unimportant.

Again the list as given in Annex D is non-exhaustive and is not intended as a checklist, but rather to stimulate creative thinking.

Annex F is provided as guidance on common risk analysis techniques that may be helpful in the identification of hazards.

H.4.4 Estimation of the risk(s) for each hazard

This is the final step of risk analysis. The difficulty with this step is that estimation of risk is different for every hazard that is under investigation as well as for every device. It was therefore decided to write the text of this subclause generically. Because hazards can occur both when the device functions normally and when the device malfunctions, one should look closely at both situations. In practice, both components of risk, probability and consequence, should be analyzed separately. When a manufacturer uses a systematic way of categorizing the severity or probability estimate levels, it should define the categorization scheme and record it in the risk management file. This enables the manufacturer to treat equivalent risks repeatably and serves as evidence that the manufacturer has done so.

Frequently, good quantitative data is not readily available. Therefore the suggestion that estimation of risk should be done in a quantitative way has been avoided.

Annex E (E.1 to E.2) has been added as helpful guidance on risk analysis. The information originates from several sources, including IEC 60300-3-9. The information in that standard was adapted to make it useful for all medical devices. Annex E does not require the construction of a “risk chart” showing the relationship between probability and severity and acceptability of risk. When risk charts are used for establishing the acceptability of a particular risk, their use and interpretation should be explained for the particular application.

H.5 Rationale for Clause 5, Risk evaluation

Decisions have to be made about the acceptability of risk. A decision was placed at this point because this is the first occasion that the required information is available. Manufacturers can use the recently estimated risks and evaluate them using the criteria for risk acceptability defined in the risk management plan. They can screen the risks to determine which ones need to be reduced. Clause 5 was written in this way to allow the user to avoid unnecessary work.

H.6 Rationale for Clause 6, Risk control

H.6.1 Risk reduction

Steps 6.2 to 6.7 make up a logical sequence of stages. This systematic approach is important since it ensures that relevant information is available when required.

H.6.2 Option analysis

Often there will be more than one way to reduce a risk. The three mechanisms listed are

- inherent safety by design,
- protective measures in the medical device itself or in the manufacturing process, and
- information for safety.

These are standard risk reduction measures and are derived from ISO/IEC Guide 51. The priority order listed is important. This principle is found in several places, including IEC/TR 60513 and local or regional regulations (e.g. the European Medical Device Directive). If practicable, the device should be designed to be inherently safe. If this is not practicable, then protective measures such as barriers or audible alarms are appropriate. The least preferred protective measure is a written warning or contra-indication.

It was recognized that one possible result of the option analysis could be that there is no practicable way for reducing the risk to acceptable levels according to the pre-established criteria for risk acceptability. For example, it could be impractical to design a life-supporting device with such an acceptable residual risk. In this case, a risk/benefit analysis may be carried out as described in 6.5 to determine whether the benefit of the device to the patient outweighs the residual risk. This option is included at this point in this International Standard to make sure that every effort was first made to reduce risks to the pre-established acceptable levels.

H.6.3 Implementation of risk control measure(s)

Two distinct verifications were included. The first verification is required to make sure that, provided the measure is implemented, the risk is reduced. The second verification is required to ensure that the measure has been implemented in the final design.

H.6.4. Residual risk evaluation

A check was introduced here to determine whether the implemented measures have made the risk acceptable. If the risk is not less than the criteria established in the risk management plan, manufacturers are instructed to assess additional risk control measures. This iterative process should be continued until the risk is reduced to within the acceptability levels established in the risk management plan.

The requirement to provide the user with relevant information on residual risks was included so that the user can make informed decisions. This requirement is consistent with the approach taken in many countries and regions, including the United States and the European Union.

H.6.5 Risk/benefit analysis

There will be some occasions where the risk associated with a medical device is greater than would be generally accepted. This subclause was included to enable the manufacturer to provide a high-risk device for which they have done a careful evaluation and can show that the benefit of the device outweighs the risk.

H.6.6 Other generated hazards

This subclause was included because it was recognized that risk control measures alone or in combination might introduce a new and sometimes quite different hazard.

H.6.7 Completeness of risk evaluation

At this stage, the risk of all the hazards should have been evaluated. This check was introduced to ensure that no hazards were left out in the intricacies of a complex risk analysis.

H.7 Rationale for Clause 7, Overall residual risk evaluation

During the process defined by Clauses 4 to 6, manufacturers identify hazards, evaluate the risks, and implement risk control measures in their design one at a time. This is the point where the manufacturer has to step back, consider the combined impact of the individual residual risks, and make a decision as to whether to proceed with the device. It is possible that the overall residual risk can exceed the manufacturer's criteria for acceptable risk, even though individual residual risks do not. This is particularly true for complex systems and devices with a large number of risks. Even if the overall residual risk exceeds the criteria in the risk management plan, the manufacturer has one last opportunity to do an overall risk-benefit evaluation to determine whether a high risk, but highly beneficial, device should be marketed.

H.8 Rationale for Clause 8, Risk management report

The risk management report is a crucial part of the risk management file. It is intended to be a summary of what was done in the risk management process. The risk management report should contain pointers to the respective details in the risk management file. The report serves as the high level document for all kinds of questions about risks associated with the device.

Completeness is very important in risk management. An incomplete task can mean that the risk of a hazard is not controlled and harm to someone may be the consequence. The problem can result from incompleteness at any stage of risk management (e.g. unidentified hazards, risks not assessed, unspecified risk control measures, or risk control measures not implemented). The risk management report is a tool that allows completeness to be judged. It does this by requiring that traceability be demonstrated for the implementation of all risk control measures required to achieve an acceptable residual risk for each hazard.

H.9 Rationale for Clause 9, Post-production information

It cannot be emphasized too often that risk management does not stop when the device goes into production. Risk management is an imperfect process because it is based on an idea with no physical manifestation of the device. Risk estimates can be refined throughout the design process and made more accurate when a functioning prototype is built. However, no amount of modeling can substitute for an actual device in the hands of actual users. This is where all the potential hazards become real. Because of this, manufacturers should monitor post-market information for things that may affect their risk estimates and, therefore, their risk management decisions. With this post-production information, the risk management process truly becomes a repetitive closed-loop process.