INTERNATIONAL STANDARD

ISO 18310-1

First edition
2017-01

Measurement and prediction of the ambient dose equivalent from patients receiving iodine 131 administration after thyroid ablation —

Part 1: During the hospitalization

Mesurage et prévision de l'équivalent de dose ambiant de patients bénéficiant d'un traitement par iode 131 après ablation de la thyroïde —

Partie 1: Pendant l'hospitalisation

Reference number
ISO 18310-1:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword ..... **iv**

Introduction ..... **v**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Measurement of ambient dose equivalent **3**
4.1 General 3
4.2 Calibration of the ionization chamber in the reference radiation 3
4.3 Measurement of ambient dose equivalent 4
4.4 Examination of uncertainty elements 6

5 Mathematical model for a calibration of ionization chamber **6**
5.1 General 6
5.2 Calibration coefficient of an ionization chamber in the reference radiation 7
5.3 Measurement of ambient dose equivalent rate using a calibrated ionization chamber in an ^{131}I radiation field 7

6 Quality control **8**

7 Uncertainty budget and estimation of uncertainty **8**
7.1 Relative combined standard uncertainty 8
7.2 Relative combined standard uncertainty of u_C [H^*(10)] 9
7.3 Expanded uncertainty 9

Annex A (informative) **Experimental application to this document: measurement and prediction of the ambient dose equivalent rate from patients receiving radioiodine 131 administration after thyroid ablation** **11**

Bibliography **22**

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

A list of all the parts in the ISO 18310 series can be found on the ISO website.

Introduction

ISO 18310 addresses measurement methods and procedures of ambient dose equivalent rate from patients administered with ^{131}I.

The incidence of thyroid cancer has increased in recent years. Thyroid cancer can be treated by administering radioiodine, because radioiodine selectively accumulates in thyroid tissue to irradiate and kill the cancerous cells. Thyroid cancers are small and not likely to develop into aggressive malignancies. Earlier diagnosis and treatment can remove these cancers at a time when they are not likely to have spread beyond the thyroid gland.

However, due to the radiation emitted from patients during treatment, the patients nearby or the caregivers could also receive the dose. For this reason, a normative way to assess the dose to persons close to the patient treated with radioiodine should be implemented. There are two common practices for the treatment of thyroid cancer, one is a radioiodine administration without thyroid resection, and the other is the administration after thyroid resection. In recent years, the radioiodine administration after surgery has become more common.

The most commonly used radionuclides for the treatment is ^{131}I. ^{131}I mainly emits 364 keV of photon energy with a few other photons and its radiological half-life is 8,02 d. The administered iodine is absorbed in the digestive system, concentrated in the thyroid gland through blood circulation and after a few hours, excreted into the bladder, and released through urine and faeces. For the patient who had the thyroid removed, the retention time in the body is shorter than that for a patient who has not had thyroid removal.

This document deals with the determination of ambient dose equivalent rate at a distance from the patient treated with radioiodine therapy procedure. It is based on the estimation of the dose rate using ionization chamber base dosimetry.

For the purpose of the ISO 18310 series, this document is focused on the determination of the ambient dose equivalent rate from the patient. The uncertainty of the ambient dose equivalent is also provided.

Measurement and prediction of the ambient dose equivalent from patients receiving iodine 131 administration after thyroid ablation —

Part 1:
During the hospitalization

1 Scope

This document specifies suitable methods for the measurement of ambient dose equivalent rate at a distance from the patient treated with radioiodine to ablate the thyroid. For this purpose, direct measurement of the ambient dose equivalent rate due to the inpatients using an ionization chamber (or other suitable devices) may be employed.

This document addresses the measurement methods, the calibration of ionization chamber and the uncertainty estimation for the measurement of the ambient dose equivalent rate of the patient treated with radioiodine to ablate the thyroid using the ionization chamber.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4037-1, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 4037-3:1999, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

ISO 29661, *Reference radiation fields for radiation protection — Definitions and fundamental concepts*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions given in ISO 4037 series, ISO/IEC Guide 99, ISO 29661 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
radioiodine
iodine-131 (^{131}I) decays with a half-life of 8,02 d with beta and gamma emissions

Note 1 to entry: On decaying, ^{131}I most often (89 % of the time) expend 971 keV of decay energy by transforming into stable ^{131}Xe in two steps with gamma decay following rapidly after beta decay. The primary emissions of ^{131}I decay are beta particles with maximum energy of 606 keV and 364 keV gamma rays. Major application of ^{131}I is for the direct radioisotope therapy to treat hyperthyroidism and some types of thyroid cancer.

3.2
air kerma
sum of the initial kinetic energies of all the charged particles liberated by uncharged ionizing radiation, such as photons and neutrons in air, divided by the mass of air

3.3
ambient dose equivalent *H(10)**
dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned ICRU sphere positioned at a depth of 10 mm along the central axis of the aligned field

3.4
ionization chamber
simplest type of all gas-filled radiation detectors that is widely used for the detection and measurement of certain types of ionizing radiation (X-rays, gamma-rays and beta particles) that collects all the charges created by direct ionization within the gas through the application of an electric field without amplification of the liberated electrons

3.5
calibration
operation under specified conditions that, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

3.6
standard calibration system
calibration system used to establish a reference condition for the *calibration* (3.5)

Note 1 to entry: It includes the reference instrument (reference ionization chamber with measurement unit of current or charge and ambient conditions such as temperature and pressure) and the standard irradiation system.

3.7
instrument to be calibrated
instrument provided by the client to the standard laboratory for calibration services

3.8
air kerma of reference
air kerma (3.2) determined by the *standard calibration system* (3.6)

3.9
reference irradiation system
irradiator unit to establish the *reference air kerma* (3.8) rate for gamma-ray or X-ray

3.10
reference irradiation method
method of obtaining a *calibration coefficient* (3.14) of an instrument by comparing the readout of the instrument with *air kerma* (3.2) rate at the calibration point determined by *reference irradiation system* (3.9)

3.11
beam size
area of the irradiation beam within which the radiation dose rate is greater than 50 % of the maximum value at the centre of the area on the reference plane located at 1 m from the source

Note 1 to entry: This term is usually defined as FWHM (full width half maximum).

3.12
effective beam size
effective area of the irradiation beam within which the radiation dose rate is greater than 95 % of the maximum value at the centre axis of the area on the reference plane located at 1 m distance from the source

Note 1 to entry: In this area, radial non-uniformity correction becomes negligible.

3.13
standard ambient condition
standard values of temperature and pressure (20 °C, 101,325 kPa) to which the dose rates of the dosimeters measured in the laboratory are corrected

3.14
calibration coefficient
factor which converts of the conventional true value of the quantity the instrument is intended to measure divided by the indication of the instrument, corrected to *standard ambient condition* (3.13)

Note 1 to entry: For example, the calibration coefficient N with respect to ambient dose equivalent measured by *ionization chamber* (3.4) is given by $N = H^*(10)/M$, where M is a dosimetric reading at the reference point of the ionization chamber.

3.15
radiation field non-uniformity correction
conversion between the dose rate at a certain point in the radiation field and the measured average dose rate over the volume of the cavity of the detector

4 Measurement of ambient dose equivalent

4.1 General

Measurement of ambient dose equivalent rate from a patient treated with radioiodine administration is done using an ionization chamber as detailed below.

4.2 Calibration of the ionization chamber in the reference radiation

The calibration procedure of the ionization chamber with respect to ambient dose equivalent by the national standard laboratory or the accredited laboratory is as follows.

The ionization chamber is calibrated using either the substitution method or the reference radiation method. In the substitution method, the measurement using the reference ion chamber and the one to be calibrated is performed at the same position with the exchange of the chambers. The calibration coefficient is then determined from the ratio of two measured values. On the other hand, the ion chamber calibration coefficient can be obtained by positioning it in the reference radiation field in which the dose rate of each position was already determined by the calibration of the radiation field.

a) The user should be trained and competent in the facility's calibration procedure prior to calibrating an ion chamber.

b) Make sure that the ionization chamber to be calibrated is in proper working condition.

c) Confirm that the centre point of the chamber is on the central axis of the beam. The central axis of the chamber stem is perpendicular to the direction of the beam and the marker or inscription on the neck of the chamber faces the radiation source.

d) Determine that the beam size is greater than the size of the sensitive volume of the chamber by a factor of 1,5 to 2.

e) Place the chamber at the calibration point and stabilize it after applying an appropriate voltage through the measuring assembly.

f) Measure the leakage current or charge of the chamber at least five times before irradiation for calibration purpose.

g) Establish and maintain environmental conditions for the calibration at 23 °C ± 2 °C, and at 50 % ± 20 % relative humidity during the measurement.

h) Upon irradiation from the standard irradiation system, measure the current or charge of the chamber more than five times.

i) If the difference is more than ±0,3 % between the initial and final current measurements or more than ±0,2 % in the atmospheric correction factor during the calibration, repeat steps f), g) and h).

j) Configuration of the irradiation system and the ionization chamber shall be arranged in accordance with the condition in Figure 1.

k) Ambient dose equivalent for the reference radiations (^{137}Cs or ^{60}Co) are obtained by multiplying the conversion coefficient $h_K^*(10)$ by the air kerma using the ionization chamber. Conversion coefficients from air kerma to ambient dose equivalent $H^*(10)$ for mono-energetic and parallel photon radiation (expanded and aligned) and the ICRU sphere is given in ISO 4037-3:1999, Table 8 and the conversion coefficients $h_K^*(10;S)$ from air kerma to ambient dose equivalent for radiation qualities of radionuclides is given in ISO 4037-3:1999, Table 8.

4.3 Measurement of ambient dose equivalent

Measurement of the ambient dose equivalents for ^{131}I using the ionization chamber during the clinical experiments is as follows.

a) During hospitalization, at certain times after the radioiodine administration, the patient shall be instructed to participate in the measurement of the current using the ionization chamber by positioning the chamber 10 cm away from the neck of the patient and 1 m away from the patient.

b) Ambient dose equivalent due to ^{131}I can be determined by multiplying the ambient dose equivalent for the reference radiation by the ratio of the conversion coefficients between ^{131}I and the reference radiation. The conversion coefficient for ^{131}I can be deduced as follows.

   1) From ISO 4037-3:1999, Table 8 of the conversion coefficients $h_K^*(10;S)$ from air kerma to dose equivalent $H^*(10)$ in the ICRU sphere for the mono-energetic photon radiation, the graph between the photon energy versus conversion coefficient can be plotted.

   2) For the energy range of 10 keV to 10 MeV, each data point can be fit to the formula $h_K^*(x) = a + b/x + c/x^2 + d/x^3 + e/x^4 + f/x^5 + g/x^6$ and thus, from the interpolation, the conversion coefficient for the gamma radiation with energy of 364 keV liberated from ^{131}I can be determined as 1,27. This fit function doesn't have a physical meaning, but in this energy range, the conversion coefficients for the radioisotopes whose values were given in the ISO 4037-3, give good matches with each other.

3) The graph is given in Figure 2 and the uncertainty of the interpolation method can be estimated from the relation, in per cent (%):

$$\sqrt{\frac{\sum\left[100\times\left(h_{\mathrm{K}}^{*\mathrm{ISO}}-h_{\mathrm{K}}^{*\mathrm{cal}}\right)\Big/h_{\mathrm{K}}^{*\mathrm{ISO}}\right]^{2}}{N-m}}$$

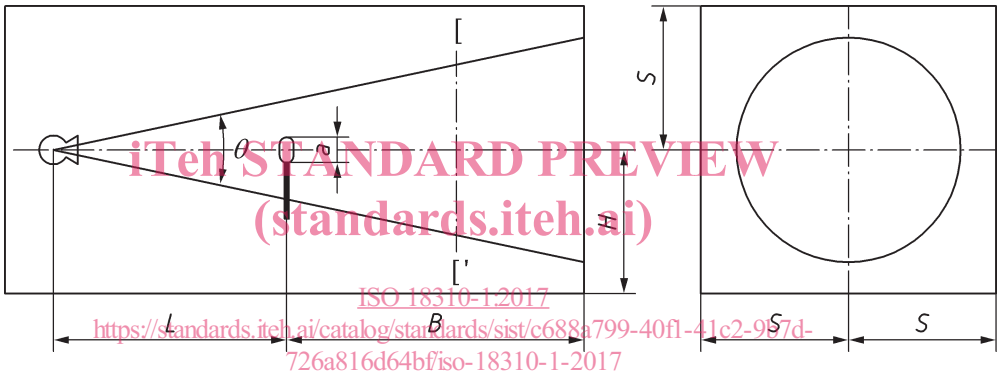
where

$h_{\mathrm{K}}^{*\mathrm{ISO}}$ is the reference value from ISO 4037-3;

$h_{\mathrm{K}}^{*\mathrm{cal}}$ is the value obtained from the fit function;

N is the number of calculation;

m is the number of parameters in the fit function.



Key

L source to instrument distance ($L > 0{,}5$ m)

a size of the detecting unit of the instrument ($a/L < 1/5$)

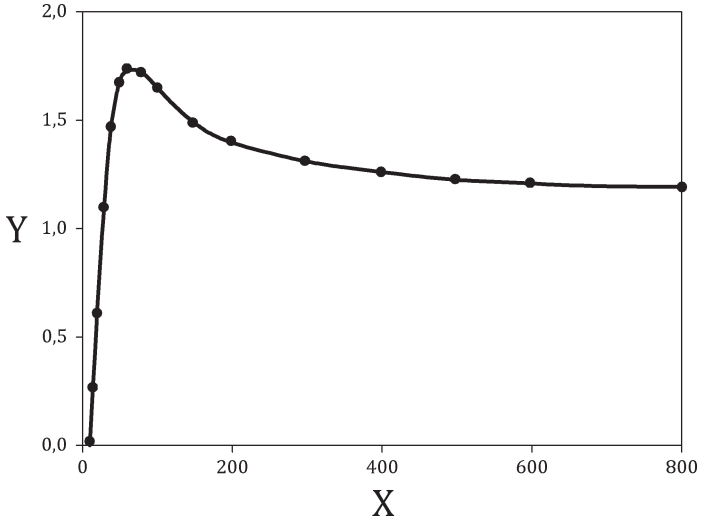
B instrument to back wall distance ($B > 1{,}5$ m)

H distance from the central axis of the beam to the floor ($H > 1{,}0$ m)

S distance from the central axis of the beam to either side wall or ceiling ($S > 1{,}5$ m)

θ angular distribution of the irradiated beam ($\theta < 40°$)

Figure 1 — Geometrical configuration of the reference gamma irradiator and the instrument



Key

X mono-energetic radiation beam (KeV)

Y conversion coefficient

Figure 2 — Plot of conversion coefficient from air kerma to the ambient dose equivalent in the ICRU sphere as a function of photon energy (referenced from ISO 4037-3)

4.4 Examination of uncertainty elements

Examine the uncertainty elements involved in the measurement and estimate the total combined uncertainty of the ambient dose equivalent from the mathematical model of the uncertainty calculation. The uncertainty of the calibration coefficient of ionization chamber is provided from the calibration certificate and it is a systematic uncertainty (type B). This uncertainty comprises the uncertainty components of the reference calibration conditions such as the current measurement, reference air kerma rate, positioning of the ionization chamber, the correction to the standard ambient conditions, radiation field non-uniformity and conversion coefficients from air kerma to dose equivalent in the reference radiation (^{137}Cs or ^{60}Co gamma-rays). Other uncertainty elements are the uncertainty of current measurement (statistical uncertainty, type A), the uncertainty of correction of ambient conditions (type B), the uncertainty of positioning the ionization chamber in ^{131}I radiation (type B) and the uncertainty of the ratio of the conversion coefficients between ^{131}I and the reference radiations (type B).

5 Mathematical model for a calibration of ionization chamber

5.1 General

The mathematical model for the calibration of ionization chambers with respect to ambient dose equivalents in the reference radiation and measurement of ambient dose equivalents in ^{131}I is as follows.

