Calibration of kerma-area product meters with a patient dose calibrator

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Patient exposure in x-ray imaging:
How big uncertainty you would tolerate?

- 100%
- 50%
- 25%
- 15%
- 10%
- 7%
- 5%

(95%, k=2)
Kerma-area product, $KAP$, $P_{KA}$  

- $KAP$ quantity is used in x-ray imaging to monitor patient exposure.
- $KAP$ is generally measured with a transparent ionization chamber.
- $KAP$ meters measure the surface integral of air kerma limited by the area of the ionization chamber ($\text{Gy} \cdot \text{m}^2$).
- $KAP$ is almost independent of measuring distance.
- $KAP \approx K_a \cdot A$ is an approximation.

\[
KAP = \int_{0}^{\infty} \int_{0}^{\infty} K_{air} \cdot dx \cdot dy
\]
Calibration of a KAP meter

- Field KAP meter should measure the radiation incident to patient.
- KAP meter should be calibrated using the same X-ray equipment and beam geometry as in actual measurements.

Motivation for the calibration

- To get **comparable** and **reliable** results, the calibration should be **traceable** to international measuring system.
- Typically meters are **adjusted** by using **one radiation quality** (spectra) and **geometry**.
- Internationally an uncertainty of < 7 % is pursued in exposure measurements*,1,2
- The aim of this study was to investigate whether **better accuracy** can be achieved by **improving the calibration procedures** for KAP meters.

* (95%, k=2)1,2
2 IAEA TRS 457 (2007)
Comparable results?

Effect of patient couch => in situ calibration?

-40%
Energy dependence

- The energy dependence should be studied in calibrations by using different radiation qualities.
- The standard (IEC 60580, 2000) for KAP meters defines ±8% limit of deviation when the total filtration is 2.5 mm Al and the tube voltage is between 50 kV and 150 kV.
- For other filtrations, no requirements are stated.
The diagram shows the calibration coefficient as a function of tube voltage (kV). The graph indicates a decrease in the calibration coefficient with increasing tube voltage. The 12% increase or decrease in the calibration coefficient is highlighted by a red box, indicating a range of 12% variation. The x-axis represents tube voltage in kV, ranging from 30 to 150, and the y-axis represents the calibration coefficient, ranging from 0.8 to 1.3.
50 kV - 150 kV: 15%
40 kV - 150 kV: 24%
Half-value layer (HVL) alone is not the answer

Toroi et al. 2008
How we do it?

Calibration methods
Calibration methods

Laboratory method:
• Field KAP meter is sent to a laboratory for calibration
• Corrective measurements are made in situ.

Beam area method:
• Reference value is measured with an air kerma meter and multiplied with the beam area.

Tandem method:
• Reference value is measured with the reference KAP meter

Uncertainties in beam area method:
Larsson et al. 1998
Tandem method

- **Reference KAP meter** is calibrated in laboratory for the incident beam.
- **Field KAP meter** is kept in the place where it is in patient measurements.
- Reference KAP meter is placed in the x-ray beam **simultaneously** with the field KAP chamber.
- The reference meter is mounted to the **distance** where entrance surface of patient usually is (> 30 cm).
Tandem method

Pros:
• Both meters measures the same quantity.
• Accurate measurements of the irradiation geometry are not required.

Cons:
• A comprehensive calibration for the reference KAP meter is needed.
• Useful beam sizes are limited by the size of the reference meter.
Patient dose calibrator, PDC

• In this study the PDC meter (Radcal) was used as a reference meter.
• The response of this meter have lower energy dependence.
• Large size of the meter made it possible to use larger field sizes.

Patient dose calibrator (PDC):
• 30cm*30cm
• non light transparent

Conventional KAP meter:
• 14 cm*14 cm
• light transparent
• strong energy dependence
Conventional KAP meter

![Graph showing calibration coefficient vs. tube voltage for different materials and thicknesses.](image)
PDC meter

![Graph showing calibration coefficients vs. tube voltage (kV).

- RQR
- 5mmAl
- 4mmAl + 0.2mmCu

Calibration coefficient range from 0.8 to 1.3.

Tube voltage range from 30 to 150 kV.

11% deviation indicated.]
Interpolations

![Graph showing calibration coefficient vs. HVL (mm Al) with data points for RQR, 5mmAl, and 4mmAl+0.2mmCu, and a 2% error margin indicated.](image-url)
Repeatability
Beam area dependence

- **In laboratory** for small range of beam sizes (Ø 42 - 96 mm) the deviation of calibration coefficient was ~1%.
- **In clinical measurements** the deviations were larger.
- Is it a problem in high rate mode or some other effect?
- In the range Ø 30 - 200 mm ≈5%
- Ø <30mm or >200 mm should not be used.
Distance between meters: field meter
Distance between meters: reference meter
Method comparison

![Graph showing method comparison with different tube voltages and calibration coefficients. The graph compares PDC high, PDC low, TaC, K*A, and LAB.]
Final conclusions

1. KAP meters should be calibrated:
   – **traceable** to international standards
   – **in situ** for **transmitted beam**
   – cover **clinically used radiation qualities**.

2. The method is not so important.
Patient exposure in x-ray imaging:
How big uncertainty you would tolerate?

• 100% No traceable calibration or
• 50% no in-situ adjustment.
• 25% One point calibration.
• 15% Limited range of RQ.
• 10% Calibration covering clinical RQs
• 7% Good calibration and use
• 5% Very difficult task

(95%, k=2), RQ = radiation quality

See also Paper 266
Hetland, Norway
Some references:


THANK YOU!