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ASSESSMENT OF PERFORMANCE OF A NEW DIGITAL IMAGE INTENSIFIER FLUOROSCOPY SYSTEM

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PURPOSE

- To study the performance of a new digital image intensifier (II) fluoroscopy system with an aim to find a potential for its optimization with maintaining good image quality at minimal dose

Quality control protocol

- Tube and generator
- HVL
- II Entrance dose rate (IIEDR) under ABC
- Patient entrance dose rate under ABC
- Radiation / image field size and distortion
- Image Quality (IQ)
  - Low contrast sensitivity (LCS)
  - High contrast resolution (HCR)
  - SNR

Siemens Axiom Iconos R200 FLC digital II (R/F) system

Fluoroscopy system

- **X-ray system:** Axiom Iconos R200 FLC digital radiography/fluoroscopy (R/F) (Siemens, Germany)
- **High voltage generator:** Polydoros SX 65/80
- **X-ray tube:** Optitop 150/40/80 HC-100 with 1.0 and 0.6 mm focal spot sizes (Siemens, Germany)
- **Image intensifier:** 40 cm Sirecon 40-4HDR fields of view (FOV): Ø 40 cm; Ø 30 cm; Ø 22cm and Ø 17 cm
- **The Automatic Brightness Control (ABC) system:**
  - three automatic programmes: 1, 2 and 3 with antiisowatt curve.
- The system is tested mainly in auto programme – “2” mode, which is the only used clinically by the medical staff

Equipment

- **Tube & generator:** Barracuda with multipurpose detector MPD (RTI Electronics, Sweden)
- **HVL:** Set of Al filters (Wellhöfer, Germany)
- **Total filtration (TF):** IPSM64 report
- **II entrance dose rate (IIEDR) & patient entrance dose rate (PEDR):** UNIDOS E with radiation transparent ionization chamber type TW34060 (PTW, Germany) and 1 mm Cu additional filtration (for II measurements only)
- **Patient equivalent phantom:** 30 cm x 30 cm PMAA slabs with up to 30 cm total thickness
- **Maximal PEDR:** 30 cm PMAA phantom plus 1,4 mm Pb (0,35 mm Pb equivalent lead apron fold in four)

Image quality assessment

- **Image quality (IQ) basic tests:** Leeds type test objects SW4, FSG4, LCD4, Hüttner type 18, SSM4, TCD4 and FL 18
- **Additional IQ tests:** Approach similar to proposed by DIMOND
  - **16 cm PMAA =** 9 cm PMAA (toward II) + FL18 + 7 cm PMAA (toward tube)
  - **20 cm PMAA** = 12 cm PMAA (toward II) + FL18 + 8 cm PMAA (toward tube)
  - **30 cm PMAA** = 18 cm PMAA (toward the II) + FL18 + 12 cm PMAA (toward tube)

IQ additional tests: SNR

- **Signal to Noise Ratio (SNR) for circle number 2 of the set up described:**

$$SNR = \frac{[BGR - ROI]}{\sqrt{STDEV_{ROI}^{2} + STDEV_{BGR}^{2}}}$$

- **ROI** is the mean pixel value in the ROI in the selected region of interest
- **BGR** is the mean pixel value in the ROI of background
- **$STDEV_{ROI}$** is the standard deviation (related to the noise) of the pixel value in the ROI inside circle number 2
- **$STDEV_{BGR}$** is the standard deviation (related to the noise) of the pixel value in the ROI outside circle number 2

IQ additional tests: SNR

- **ImageJ 1.37v** software was used for ROI calculations of the phantom DICOM images
- The DICOM images are exported in 1024 × 1024 pixels and 10 bits depth at the server of the Radiology Information System (RIS)
- The evaluation was performed in the Laboratory using a desktop PC (Dell, Ireland)

Figure of Merit

- From the values of SNR and ESD the Figure of Merit* was calculated using the formula:

$$FOM = \frac{SNR^2}{ESD}$$

** Zamenhof Med. Phys (1982)*
** Vano at al PMB (2005)*

RESULTS

X-ray tube and generator performance

Parameter, (unit)	**Value**	**Tolerance (Remedial level)***
Max. U_a inaccuracy (%)	5,8	≤6
Ua consistency (%)	0.2	≤5
TF (mm Al equiv.)	3.0	≥2.5
Timer consistency (%)	5	≤10
Output, Y, at 81 kV (μGy/mAs at 1m)	59.6	26<Y<69
Output consistency, (%)	0.1	≤15
Output variation with mA, (%)	3.1	≤15
Power, n, of the Y variation with kV	1,9	1.7<n<2.5

** Ordinance 30/2005 for Protection of Individuals at Medical Exposure (Bulgaria), – Based on EC RP 91 and some National standards (mainly IPEM)*

IQ basic tests

Parameter	Remedial Level*	Measured value	Acceptable? (Yes/No)
II EDR	≤ 800 nGy/s for 25 cm FOV and no grid in place	40 cm FOV:128 nGy/s 30 cm FOV: 162 nGy/s 17 cm FOV: 499 nGy/s	YES
Max PESDR	50 mGy/min	48.5 mGy/min	YES
High contrast resolution	≥0,8 mm^{-1} for FOV > 30 cm	40 cm FOV: 1,6 mm^{-1} 30 cm FOV: 1,8 mm^{-1}	YES
Low contrast sensitivity	≤ 4 %	40 cm FOV: 1,8%; 30 cm FOV: 1,8%; 22 cm FOV: 1,3%; 17 cm FOV: 1,8%.	YES
Radiation to Image Field Size	Ratio of areas <1.15	40 cm FOV: 0,97 30 cm FOV: 1,03 22 cm FOV: 1.03	YES

** Ordinance 30/2005 for Protection of Individuals at Medical Exposure*

ESDR vs. Dose mode
@ 15 and 30 p/s & 40 cm FOV

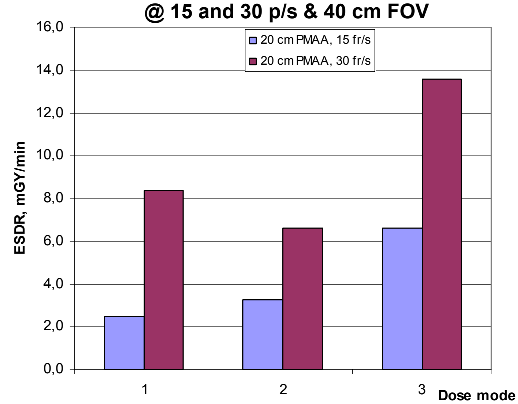
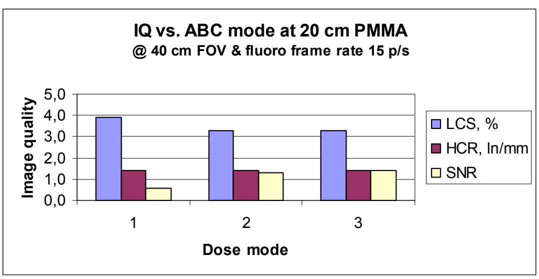
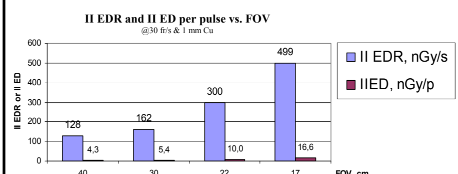
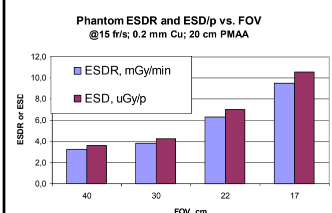


Image quality vs. Dose mode



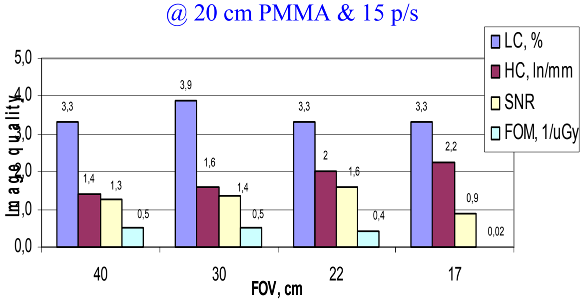
II (EDR & ED) and Phantom (ESDR & ESD) vs. FOV





II (EDR & ED) and Phantom (ESDR & ESD) are increasing with reduction of FOV, as expected.

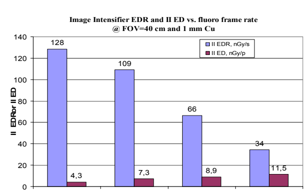
Image quality vs. FOV
@ 20 cm PMMA & 15 p/s

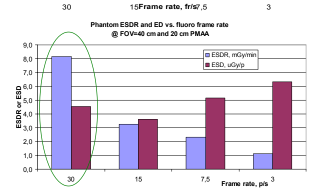


LCS remains practically constant (3.3 – 3.9%), HCR increases from 1.4 to 2.2 lp/mm, SNR first increases from 1,3 to 1,6 and then is dropping down to to 0.9, ESDR increases with factor of 3

The FOM is decreasing 31 times at FOV from changing from 40 to 17 cm

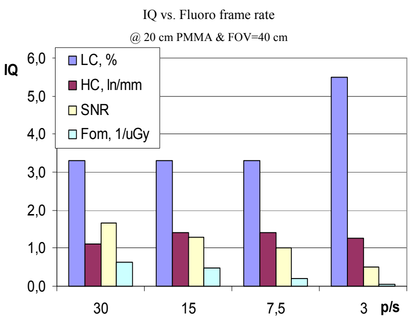
Dose vs. Fluoro frame rate





- The phantom ESDR decreases with frame rate reduction.
- The phantom ESD/p decreases with increase of the frame rate with exception for 30 p/s mode, at which no additional Cu filter is placed in the beam.

Image quality vs. Fluoro frame rate



That shows a potential for an optimization of clinical examinations using 7.5 instead of 15 p/s in some cases. The unit is dedicated mainly to contrast gastrointestinal and renal examinations and the use of higher pulse rate is not necessary during the whole examination.

ESDR and ESD/p vs. PMAA thickness

@15 p/s; 0.2 mm Cu; 40 cm FOV

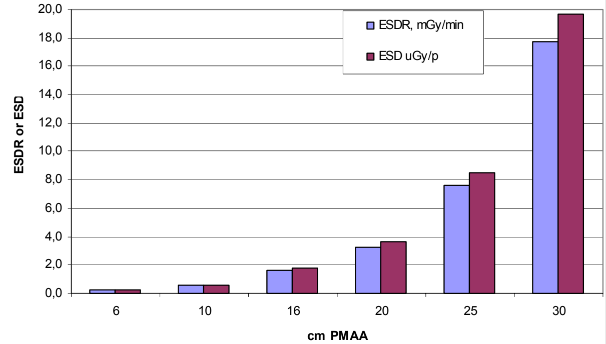
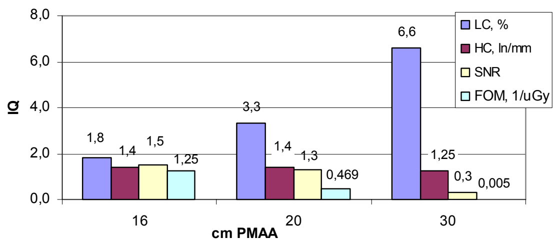


Image quality vs. Phantom thickness

@ 15 p/s, 40 cm FOV, 0.2 mm Cu



The image quality diminishes critically with the increase of PMMA phantom thickness from 16 to 30 cm (especially from 20 to 30). Until the HCR remains relatively constant (1.25 – 1.4 ln/mm), the threshold LCS increases from 1.8 to 6.6%, the SNR decreases from 1.5 to 0.3, as the ESDR increases with factor of 11 This deterioration of the system performance is clearly illustrated by the considerable reduction of FOM by factor of 250 (from 1,250 to 0.005 μGy^{-1})

CONCLUSSIONS

- The system satisfies completely the patient dose and the image quality criteria relevant to conventional fluoroscopy for the typical phantom thickness
- This study shows the weak points of the standard protocols applied to more sophisticated digital systems and the importance of performing additional image quality and dose assessments in non reference conditions

CONCLUSSIONS

- The additional assessment methods applied in this work can serve as a basic tool for its further optimization.
- A further conduction of a real patient dose survey is expected to demonstrate to the medical staff the importance of technical parameters selection for the patient dose received. It will make easier understandable the results from the phantom image quality and dose studies and the potential for optimization of their system.

Thank you for your attention!

Table. Results from the additional QC assessment

Variables				Surface dose rates at 20 cm PMMA		IQ measured with FL18 between 12 cm and 8 cm PMMA			
FOV (cm)	Frame rate (p/s)	Additional Cu filter (mm)	PMMA (cm)	ESDR (mGy/min)	ESD (µGy/p)	LCS (%)	HCR (ln/mm)	SNR	FOM (nGy^{-1})
40	30	0.0	20	8.2	4.5	3.3	1.12	1.7	642
40	15	0.2	20	3.3	3.6	3.3	1.4	1.3	469
40	7.5	0.2	20	2.3	5.2	3.3	1.4	1.0	192
40	3.0	0.2	20	1.1	6.3	5.5	1.25	0.5	40
40	15	0.2	16	1.6	1.8	1.8	1.4	1.5	1250
40	15	0.2	20	3.3	3.6	3.3	1.4	1.3	469
40	15	0.2	30	17.7	19.7	6.6	1.25	0.3	5
40	15	0.2	20	3.3	3.6	3.3	1.4	1.3	469
30	15	0.2	20	3.8	4.3	3.9	1.6	1.4	456
22	15	0.2	20	6.3	7.0	3.3	2.0	1.6	366
17	15	0.2	20	9.5	10.6	3.3	2.24	0.4	15