IAEA-CN-85-167

EXPERIMENTAL DETERMINATION OF BLURRING IN X-RAY FLUOROSCOPY LAST IMAGE HOLD DUE TO PATIENT MOVEMENT AND ITS REPERCUSSION TO PATIENT DOSES.

E. Guibelalde[1], E. Vañó[1,2], J.M. Fernández[2], L. González[1], J. Alberdi[3], A. Molinero[3]
[1] Física Médica, Dpto. Radiología, Fac. Medicina, Univ. Complutense, Madrid, Spain
[2] Servicio de Física Médica, Hospital Clínico San Carlos, Madrid, Spain
[3] Sección de Electrónica y Automática, CIEMAT, Madrid, Spain

Abstract

Significant dose reduction can be achieved in fluoroscopy and interventional radiology by using the last image hold (LIH). This feature in modern digital fluoroscopy x-ray units usually works with frame or temporal averaging techniques to reduce noise. This image quality works quite well for objects without motion but it could be a serious limitation in presence of motion blur. With an in-house developed robotic device, authors have experimentally determined the image quality degradation introduced by normal physiological movements (i.e., respiratory and cardiac pulse movements). FAXIL test objects TO.10 and 18FG from Leeds University have been used for spatial resolution limit and threshold contrast detail detectability. Seven X-ray equipments with last image hold features from three different manufacturers were analysed. Although results show that motion blur affects LIH in different extend depending on equipment, magnification, entrance dose and detail size, it can be estimated that, on average for all equipments and analysed conditions, represents 30% degradation in image quality parameters in comparison with static images.

1. Introduction

One of the most effective ways for reducing patient doses in fluoroscopy and in interventional radiology fluoroscopy guide procedures is to minimise fluoroscopy time. For that, Last Image Hold (LIH), is a powerful tool. The last image acquired is presented continuously on the monitor until fluoroscopy is once again activated. Meanwhile, radiologists could decide about the diagnosis and further actions to be taken. In the case of an image sequence, the temporal filtering properties of the human visual system reduces perceived noise. In the case of a single constant image (such as LIH) this mechanism does not work and the image looks noisier and low contrast details disappears [1]. For that reason, it is well known that motion affects LIH and in principle it is contradictory to improve the SNR by summation frames or by temporal filtering and at the same time refrain from motion blurring for the same image. There have been some perception studies [2] on motion blurring in x-ray fluoroscopy, but in our knowledge there is not any experimental publication on motion blurring in LIH fluoroscopy. In addition, there are different possibilities to reduce system noise and manufacturers usually do not provide enough information about their designs, among them, summation of 2 frames accumulated in the digital memory, summation of 4 frames in the same way, use of recursive filters with different k factors (weight factors) or use of movement detection circuits [3].

Authors have developed a computer controlled device able to reproduce patient motions and in which it is possible to insert different types of test objects to evaluate image quality in the presence of motion. In this paper, using this device an experimental determination of the degradation of the spatial resolution and low contrast detail perception caused by patient and organ motion is presented for some X-ray equipment with Last Image Hold fluoroscopy.

2. Material and method.

We have designed and constructed a prototype of 2-D motor controlled phantoms with the preliminary goal of simulating clinical situations in which patient movement could be a cause of image degradation or rejection. PAtient MOvement Simulation Test Object (PAMOSITO) was constructed with modular parts to use different mobile test objects and static structures (See [4] for a first PAMOSITO design and applications] The system allows programming different cycles of movement along two axes (x and z). PAMOSITO features two step motors for the z axis with a 50 mm range to simulate the patient respiratory movement and small displacements in X-ray oblique projections. The test object can be moved along the x axis by means of a linear motor with a 145 mm range. The linear motor by Linmot© (Sulzer Electronics AG) allows 500 mm/s of maximum velocity (in increments of 190 mm/s) and 1000 mm/s^2 (in increments of 238 mm/s^2) and is a direct linear drive with integrated position sensing. Those excellent dynamic properties make it possible to simulate very close cardiac pulses or quick involuntary movements.

A layer of 2 mm of copper was used to simulate the patient absorption. The test objects employed for the image quality evaluations were TOR(TO.10) and 18FG for fluoroscopy, from FAXIL [University of Leeds, UK]. The evaluation methodology followed the FAXIL recommended viewing protocol [5]. Three observers scored images for low contrast detectable discs and for high contrast spatial resolution limit. Spatial resolution grid was placed 45° respect the x-motion axis.

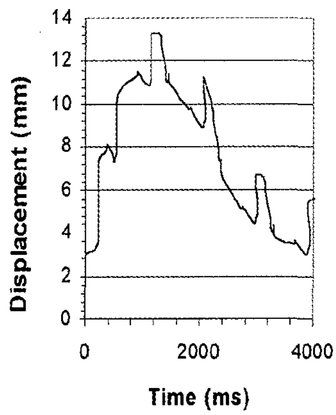

Figure 1: Motion curve loaded into the electronics of PAMOSITO representing a quiet breathing plus a cardiac pulse

PAMOSITO with TO.10 and 18FG test objects was used with the motion curve presented in figure 1, which corresponds to a quiet breathing plus a normal cardiac pulse. This type of motion closely mimic a clinical situation with a sedated patient and it does not affect continuos fluoroscopy. In fact, no significant differences were observed in the fluoroscopy images with this motion curve between the static test object image and the corresponding motion test object images, for all X-ray systems studied. Phantom entrance doses were measured with a RADCAL 2025 external ionising chamber. Doses were normalised at 50 cm phantom entrance surface. Seven different X-ray installations with fluoroscopy and LIH in clinical use for different specialities (vascular, digestive, neurorradiology, and multipurpose systems) were studied. X-ray units were: Toshiba Max1000 (2 units), Toshiba KX080G, Toshiba KXO SDF, Siemens Digitron, Philips BV300 and Philips Omnidiagnost. Image systems admit different magnification, so that images were evaluated for 23 cm, 17 cm and 15 cm fields.

3. Results

Comparative results for high contrast spatial resolution limit in three situations (continuous fluoroscopy with the static phantom, LIH with the static phantom and LIH with the curve motion of figure 1) are shown in Table I for different equipments and for different magnifications. As examples of Contrast Threshold Detail Curve results Figure 2 to 5 are presented for two different equipments and two different magnifications.

TABLE I. Reduction of Spatial resolution limit in lp/mm for Last Image Hold with and without patient motion.

	FIELD 23 cm			FIELD 17 cm			FIELD 15 cm		
X-ray equipment	Fluoro No motion	LIH No motion	LIH Motion	Fluoro No motion	LIH No motion	LIH Motion	Fluoro No motion	LIH No motion	LIH Motion
Toshiba KX080G	2.0	1.8	1.4	2.5	2.5	2.0	3.1	3.1	2.2
Toshiba XKO SDF	1.4	1.4	1.1	1.8	1.8	1.4	2.5	2.5	1.8
Toshiba Max1000 (room1)	1.8	1.8	1.4	2.2	2.0	1.4	2.8	2.5	1.6
Toshiba Max1000 (room 2)	1.4	1.4	0.9	2.0	2.0	1.2	2.8	2.8	2.0
Siemens Digitron	1.0	1.0	0.8	1.2	1.1	0.9	18	1.6	1.1
Philips BV300	1.6	1.4	1.1	2.0	2.0	1.8	--	--	--
Philips Omnidiagnost	1.2	1.2	0.9	2.0	2.0	1.1	2.5	2.5	1.4

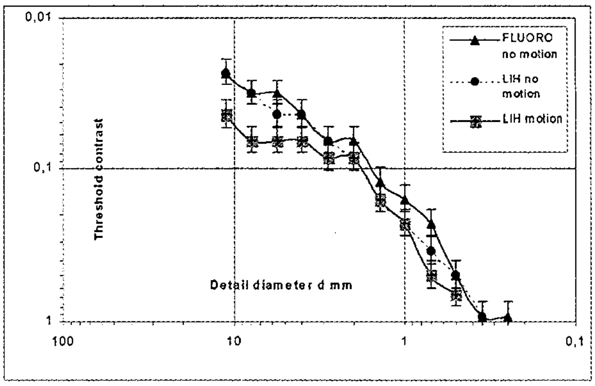

Figure 2: TCDD curve for LIH with and without motion.
Philips Omnidiagnost - Field 23 cm– 71 kV – 14,9 mGy/min

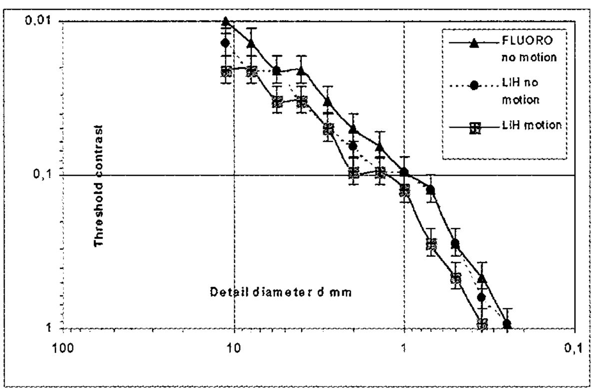

Figure 3: TCDD curve for LIH with and without motion.
Philips Omnidiagnost - Field 17 cm– 74 kV – 25,1 mGy/min

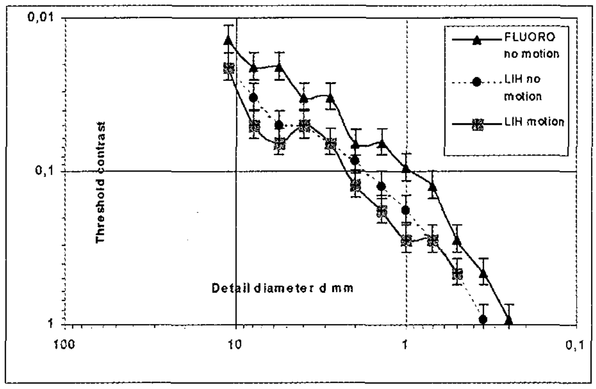

Figure 5: TCDD curve for LIH with and without motion.
Toshiba Max 1000 - Field 17 cm- 75 kV - 16,8 mGy/min

4. Discussion

Note from table I that in the case of no motion spatial resolution is for most situations not affected (on average for all equipments and magnification, the spatial resolution loss can be estimated in 3,5%). This was expected since LIH does not introduce changes in the spatial resolution properties of the system and as mentioned before manufacturers introduce some noise reduction techniques so that noise is not usually a limitation for the spatial resolution limit. However motion blurring affect the LIH significantly and it is more important in magnification modes. On average for all equipments, the loss of spatial resolution is 26,5% (field 23 cm), 28,5% (magnification mode; field 17 cm) and 35% (magnification mode; field 15 cm) respect the corresponding fluoroscopy image. This fact must be known by interventional radiologists since magnification usually requires higher surface entrance patient doses. For example the phantom entrance dose for the Philips Omnidiagnost equipment (last row in table I) was 14,9 mGy/min (field 23 cm), 25,1 mGy/min (field 17 cm) and 39,4 mGy/min (field 15 cm). Note in last row of table I that the improvement of spatial resolution achieved by using the magnification is lost by the LIH with patient motion.

As stated in the introduction more significant losses are observed both for LIH with static objects and LIH with motion objects for Low Contrast Detail sensitivity. Here, we have observed differences depending not only on magnification (compare figure 3 and figure 5 respect figure 2 and figure 4) but on the manufacturer equipment and model (which likely could be explained by use of different temporal filters or number of added frames to built the last image hold). The equipment for figures 2 and 3 shows little degradation when using LIH in static object and an important extra degradation for LIH in moving objects, on the contrary, the equipment for figures 4 and 5 shows an important degradation for LIH and static objects and a little extra degradation for LIH and moving objects. On average for all equipments, magnifications and detail sizes the loss in contrast detail sensitivity for LIH and moving objects is 30% respect to the corresponding fluoroscopy images.

5. Conclusions

Although results show that motion blur affects LIH in different extend depending on equipment, magnification, entrance dose and detail size, it can be estimated that, on average for all equipments and analysed conditions, represents 30% degradation in image quality parameters. Degradation is more important in magnification modes so that radiologists should be known this fact to optimise their protocols. Manufacturers should be encouraged to improve image quality of LIH both for static and motion structures since it use is essential for patient dose reductions.

Acknowledgements

This project is partially supported by the Spanish CICYT (project n. PM97-0059-C02-01).

References

[1] WILSON, D. L., XUE, P., AUFRICHTIG, R., Perception of fluoroscopy last-image hold. Med.Phys. **21** (1994) 1875-1883.

[2] XUE, P. WILSON, D.L., Effects of motion blurring in x-ray fluoroscopy. Med. Phys. **25** (1998) 587-599.

[3] VERHOEVEN, L., "Design considerations of digital fluoroscopy/fluorography equipment", Secification, acceptance testing and quality control of diagnostic X-ray imaging equipment. Seibert J.A., Barnes G.T., Gould, R. G. Editors. American Association of Physicists in Medicine. Medical Physics Monograph No, 20. (1994) 651-707.

[4] GUIBELALDE, E., MERILLAS, A., VAÑÓ, E., MOLINERO, A., ALBERDI, J. AND FERNÁNDEZ J.M. Design of a PC controlled test device for the study of patient motion in X-ray radiology: first application and results. Br. J. Radiol. **71** (1998)1185-1191.

[5] LAUNDERS, J. H., MCARDALE, S. WORKMAN, A., COWEN, A. R. Update on the recommended viewing protocol for FAXIL threshold contrast detail detectability test objects used in television fluoroscopy . Br. J. Radi **68** (1995) 70-77.