



Strahlenschutzkommission

Geschäftsstelle der
Strahlenschutzkommission
Postfach 12 06 29
53048 Bonn

<http://www.ssk.de>

Data compression of X-ray images

Recommendation by the German Commission on Radiological
Protection

Adopted at the 252nd meeting of the German Commission on Radiological Protection on
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Datenkompression bei Röntgenbildern

Stellungnahme der Strahlenschutzkommission

This translation is for informational purposes only, and is not a substitute for the official statement. The original version of the statement, published on www.ssk.de, is the only definitive and official version.

1 Background

Radiological imaging generates large data volumes in the form of X-ray images for diagnosing. These data volumes still constitute an immense challenge for individual radiology practices or hospitals, either when complying with the archive provisions of the German Röntgenverordnung (RöV: § 28 para. 5) or distributing images swiftly among specialists as part of the diagnostic process or teleradiology. There are no concerns to apply a lossless image compression. In the case of lossy compression, however, technical recommendations are needed that specify under what conditions and to what extent image data may be compressed. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety therefore asked the SSK to produce a statement on the practical application of the provision found in § 28 para. 5 sentence 2 of the RöV, “*X-ray images may be compressed for archiving on electronic storage media if it can be guaranteed that their diagnostic validity is preserved*”. This statement aims at a pragmatic approach, without trying to clarify the fundamental definitions (diagnostic image, raw image, raw data, basic image) or the question, which digital information requires archiving.

Image compression relating to DICOM¹ data formed the subject of a consensus conference (Loose et al. 2009) attended by radiologists, medical physicists, industry and public authority representatives. Taking the 56 highest-scoring studies, selected from 216 publications, as well as the largest recently published study from Canada as a basis, it was discussed whether - and taking which factors into account - image compression is possible without compromising on diagnostic quality. The results of this conference, attended by more than 80 experts, was published in the German journal “RöFo - Fortschritte auf dem Gebiet der Röntgenstrahlen und bildgebenden Verfahren” at the beginning of 2009. This recommendation by the SSK refers to the “RöFo” publication and other quoted references.

The following assumes that ensuring the image quality for diagnosis guarantees to ensure the image quality requirements for archiving (§ 28 para. 5 sentence 2 RöV).

In contrast to lossless compression, which allows the exact image contents to be restored upon decompression, the lossy compression techniques change the image content, even though the image matrix and image depth (greyscale levels) remain the same. The requirement is, that for the purposes of diagnosis, image information and image quality cannot be distinguished.

Only those studies which examined the impact of compression ratios on the quality of diagnosis (e.g. ROC² analyses) were included in the assessment of compressed image quality. In this context it is important to bear in mind that, from an information theory point of view, simply because it is not possible to distinguish between different ROC curve areas, does not mean that the significance of each little modification actually remains the same. The design of the studies and the cases selected, which generally reflect everyday’s clinical routine, do not support such analysis. Nevertheless the selection is appropriate for daily clinical practice.

It is against this backdrop that the somewhat conservative specification of compression ratios needs to be considered. During the process it also became apparent that only image data compression methods which are in full compliance with the DICOM standard should be used.

Moreover, it should be pointed out that X-ray images from mammography screening were intentionally excluded from the recommendations owing to existing legal restrictions, despite

¹ DICOM: „Digital Imaging and Communications in Medicine“ is a National Electrical Manufacturers Association (NEMA) standard for storing, printing and transmission of medical images (<http://medical.nema.org/>)

² ROC: In signal processing theory „Receiver Operating Characteristic“ or ROC curve is a graphical representation of the ratio sensitivity versus false positive results.

the fact that it would have been possible to specify compression ratios for these images which would have ensured the preservation of their diagnostic validity (diagnostic quality), as foreseen by the studies under consideration. The SSK maintains this approach and therefore has not specified any compression ratios in this instance.

Ultrasound and nuclear medicine images were excluded owing to their overlap with other scientific medical societies.

Table 1, extracted from the 2009 publication by Loose et al., shows the individual compression ratios to be allocated to the various modalities and types of examination.

For some modalities, such as surgical navigation or radiotherapy planning systems, the use of lossy-compressed DICOM files is mostly deactivated. As well as a possible failure to implement the standard, or licence fees incurred, one reason for this could be uncertainty as to whether compression would affect the subsequent processing of the images and any results. The recommendation issued by the British Royal College of Radiologists (RCR 2008) emphasises that the different reconstruction kernels used in a clinical routine are likely to have a greater impact on the post-processing of image data than lossy compression. No compression ratio recommendations have been made for these applications, since no relevant studies exist.

With compression ratios of 1:48, CAD (computer assisted detection) programs designed to process images automatically, as in the automatic detection of solitary pulmonary nodules during a CT scan, tolerate values considerably higher than those recommended by the consensus conference without affecting the volume of the nodules detected (Raffy et al. 2006, Ko et al. 2005). These results however remain the subject of controversy. This recommendation issued by the SSK therefore takes a more conservative line.

In the meantime the European Society of Radiology (ESR) has published an appropriate recommendation in the form of a white paper (ESR 2011). On the one hand, this publication approves the use of lossy image compression when applied within the scope of current national recommendations, and on the other addresses a whole range of issues, some requiring additional research, others further specification. These include:

- The significance of differences in quality ratio with regard to JPEG compression, and compression ratio in the case of JPEG2000 compression.
- The observation that when setting a compression ratio, it is not the bit number (generally 2 bytes) allocated for the greyscale display that counts, but the stored bit number (e.g. 12 bits).
- The impact of high-frequency image information (e.g. noise) versus smoothed/filtered image files on tolerable compression ratios.
- The effect of purely black and white burned in overlays or graphics within an image on compression.
- The range of results produced when thick and thin CT slices are compressed using compression ratios between 1:8 and 1:16 (note: these compression ratios exceed the recommendations of the German consensus conference).
- The creation of measuring and quality assurance systems to enable the uniform comparison of different compression rates and techniques.
- Negotiations with the industry aimed at reaching a consensus on uniform standards for the implementation of lossy image compression.

Any potential correlations between image compression and possible dose reduction during image acquisition do not feature in this recommendation and will form the subject of subsequent research.

2 Recommendation

The application of image compression is one possible step of mathematical image processing, forming an imaging chain from the initial X-ray through to archiving or image distribution. The physician with the necessary expertise in radiation protection must therefore ensure that the selected compression technique and archive system used will be adequate to preserve the diagnostic image quality.

To ensure the complete preservation of diagnostic image quality, the SSK recommends not to exceed the compression ratios (table 1) published by the German consensus conference when compressing medical DICOM images. The published compression ratios refers to the JPEG and JPEG2000 compression algorithms.

By following the maximum recommended compression ratios for reporting and archiving, it can be ensured that both the medical and radiation protection requirements of the RöV, and specifically of § 28 para. 5, sentence 2 of the RöV, “X-ray images may be compressed for archiving on electronic storage media if it can be guaranteed that their diagnostic validity is preserved”, are fulfilled according to the information currently available.

An evaluation should be done within five years of publication of this recommendation whether the existing recommendation on radiological image compression is still commensurate with any new findings.

Table 1: Compression ratios

Imaging method	Organ	Compression ratio
CT	brain	1 : 5
CT	abdomen	1 : 8
CT	thoracic soft tissues	1 : 8
CT	lung	1 : 8
CT	skeleton	1 : 8
CR/DR	lung	1 : 10
CR/DR	musculoskeletal system	1 : 10
CR/DR	abdomen	1 : 10
CR/DR	mammography	1 : 15
MR	all applications	1 : 7
RF/XA	fluoroscopy/DSA/coronary angiography	1 : 6

CT: Computer tomography
 CR/DR: Digital radiography (imaging plates/flat panel detectors)
 MR: Magnetic resonance imaging
 RF/XA: Fluoroscopy/angiography

3 Bibliography

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