# Interoperability for Image and Non-Image Data in the DICOM Standard Investigated from Different Vendor Implementations

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**Abstract**

*DICOM conformity alone does not guarantee the interoperability of imaging equipment developed by different parties. In a survey the DICOM datasets of 19 complete angiographic examinations have been compared.*

*It was found, that most datasets are DICOM compliant and image data are encoded in a similar way. On the other hand the interoperability of non-image data has been found to be very limited. Especially data concerning patient demographics, time synchronization, contrast agent and acquisition information are missing or encoded in different ways. Reasons were misinterpretations by manufacturers and ambiguous definitions in the DICOM standard.*

*Furthermore it was realized, that incorrect encoding could often not be found by automatic validation tools: In contrast manual examination and expert knowledge is necessary to understand problems in interoperability.*

## 1. Introduction

Digital data exchange is highly dependent from standardized data formats and communication protocols. A very large number of possible coding permutations is opposed by a limited flexibility in decoding. The daily practice shows, that it is quite common, that datasets like database tables, text documents or even image data cannot be decoded at all. The requirements for exchanging data in clinical routine including interpretative contents go far beyond the requirements for data exchanging unstructured data like word documents or HTML files. Additionally to the proper encoding and decoding, the meaning of the contents must be identical for encoder and decoder. This includes an identical understanding of the meaning and the relevance of the data.

For an international standard like DICOM the problem is extended to a very broad range of clinical users and technical implementers. They all need to have an identical understanding about the meaning of the data contents. This is a very extensive demand, that can only be reached partially.

The DICOM standard contains rules both for encoding data and for representing clinical meanings in a structured manner [1]. The goal of DICOM is to enable the interoperability of medical equipment in clinical practice. In this contents the word 'interoperability'm eans much more than 'connectivity'.

In several approaches the DICOM compliance of datasets were examined. With elaborated software tools DICOM objects are decoded, modules detected and finally the header information be validated. Doing this, several missing or misused attributes can be detected. Especially conditions for the presence of attributes and correct encoding can be tested automatically [2-3].

DICOM compliance is necessary for interoperability, but does not guarantee it. Interoperability requires a comparison between datasets and DICOM interfaces. For DICOM interoperability testing a different approach must be used.

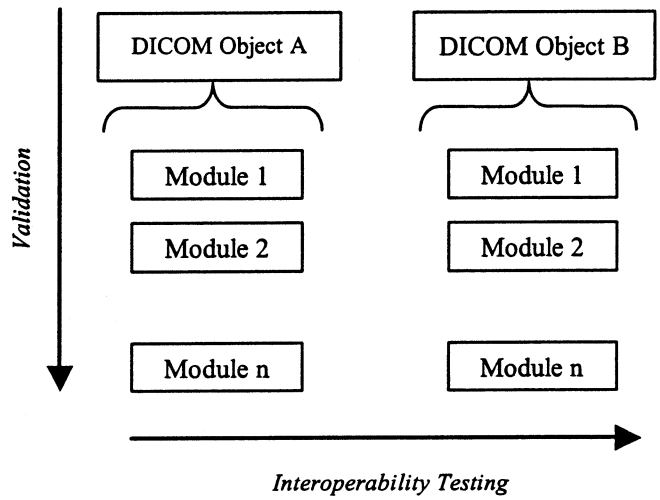


Figure 1. DICOM Validation is performed by examining only one DICOM object at a time. Interoperability testing always includes a comparison of multiple datasets.

## 2. Interoperability

In order to find a appropriate definition for interoperability, the process of exchanging data can be separated in three independent parts. Figure 2 shows a general communication model, that can be used for any means of communication, like spoken language, written signs or even digital data exchange.

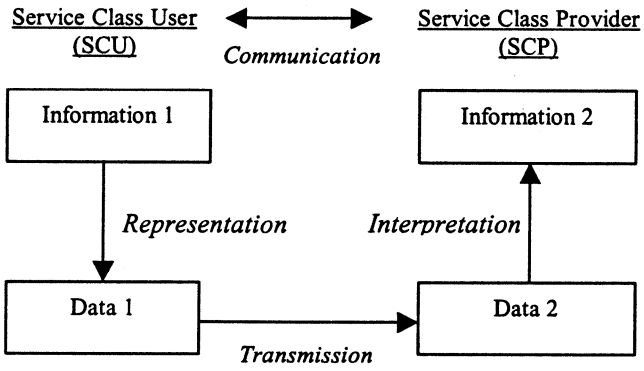


Figure 2. For the communication of two parties, the sender (SCU) needs to represent the information in machine readable data, that can be transferred to and re-interpreted by the receiver (SCP).

In order to enable a communication, the sender represents the medical information in defined terms and encodes it into machine readable data. These data can be exchanged using any available media. The receiver needs to decode and interpret these data, in order to understand the content. If all this is done, the communication between the two parties is enabled. This model can be used to formulize three questions of interoperability:

1. Are the two systems able to exchange data?
2. Is the represented (by the sender) and interpreted (by the receiver) information identical?
3. Is the exchanged set of data sufficient for the clinical workflow?

A similar approach can be found in [4]. In this paper, the interoperability testing is focussed on the representation/interpretation aspect. It shall be examined, whether the representation of real world information is comparable in angiographic datasets of the major vendors.

## 3. Method

For the survey DICOM datasets of 19 complete angiographic examinations including 259 image objects have been used. All datasets were created in clinical routine by different imaging systems and software versions of the main vendors in the years 1996-2001. Datasets of the vendors General Electrics, Philips, Siemens and Toshiba are included.

For the automatic comparison a program was developed, that extracted all attributes from the image objects and stored them into a database. This database was used to compare the usage of the data elements module by module in a structured manner. This comparison has been performed manually, and included both the representation and the values of the contents. The latter aspect is necessary to realize differences in the vendor specific standard interpretation and implementation. Additionally the available datasets were compared with the official definitions in the DICOM standard.

## 4. Results

The administrative data contained the patient name and identification in 18 of the 19 datasets. In 16 datasets, the patient name did not contain DICOM specific separators for first, last and middle name. The patient 'Jon W. Doe' should be encoded as 'Doe^Jon^W'. In practice, data like 'Doe, Jon W.' or 'Jon Doe' were found. Additionally the patient ID was in all cases not an unique patient identification, but an examination number. This number should rather be used as a study ID. The patients date of birth was coded correctly in all cases.

Both for the hospital and the equipment several information's can be encoded in DICOM. These data can be helpful to identify a hospital, the cathlab, the acquisition system and the manufacturer. The institution name was absent in 2 and the address in 15 datasets. The system model name was missing 9 times and the manufacturer name 6 times. The station name, the system or cathlab name in a department, was not encoded in any of the datasets. All these attributes are of type 2. This absence is not a standard violation, but decreases interoperability.

All attributes, that are required for image data decoding, like 'Bits Allocated', 'Samples per Pixel', 'photometric interpretation' etc. were present and used identically in all examined 19 datasets. A relevant miss was the absence of the 'offset table'i n one dataset. The offset table is not required, but allows fast access to single frames in multi-frame image objects.

The module 'X-Ray Acquisition' contains information about the X-Ray generator and detector settings. It was found, that the vendors used the 'X-ray tube current'i n different ways. Some vendors encoded peak values, others mean values. Additionally a misinterpretation of the attributes ,Intensifier Size' and 'Field of view' was found. The intensifier size is fixed for an intensifier and the field of view can vary. However, only one manufacturer used the attributes correctly. The other vendors varied the value of the intensifier size instead of 'field of view'.

The module 'Contrast Bolus' is required, if contrast agent is used during image acquisition. Although this condition is true for all angiographic acquisitions, it is used in two datasets only.

| Attribute Name | A1 | A2 | A3 | A4 | B1 | B2 | B3 | B4 | B5 | C1 | C2 | C3 | C4 | C5 | D1 | D2 | D3 | E1 | F1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Date/Time | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Series Date/Time | + | + | + | + | + | + | + | + | + | - | - | - | - | - | - | + | - | - | - |
| Content Date/Time | + | + | + | + | - | - | - | - | - | - | - | - | - | - | + | + | + | - | + |
| Acquisition Date/Time | + | + | + | + | + | + | + | + | + | - | - | - | - | - | - | + | - | - | - |
| Acquisition Datetime | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Frame Delay | + | + | + | + | + | + | + | + | + | - | - | - | - | - | - | - | - | - | - |
| Frame Time | - | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Frame Time Vector | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Instance Creation Date/Time | - | - | - | - | + | + | + | + | + | - | - | - | - | - | - | - | - | - | - |

Table 1: As an example for the results of interoperability testing, the usage of the attributes for date and time coding are compared. The 19 datasets A1-F1 use the available attributes in a very different manner. The information of date and time of the study is the only proper encoded attribute. Attributes indicated by a '+' are present and correct encoded, those with a '-' are absent.

The attributes for time coding were used very different. In the DICOM standard the type 2 attributes 'content date/time' have a higher priority than the type 3 attributes 'Acquisition date/time'. For purposes of time synchronization, the second attributes are more relevant. However, only one vendor used in all its datasets both attribute pairs, one vendor used only 'acquisition date/time' and one vendor none of both. The only date and time information, that was always available, was 'Study Date/Time', that describes the start of the examination (see table 1).

## 5. Discussion

The presented data show, that in all datasets the attribute values for the image data are of maximal consistency and lead to a very high interoperability. The quality of the additional data is much lower. Most administrative data were presented, but could even not be used to separate first and last name in a safe way. The patient ID does have several meaning. It should be a unique identification generated by the hospital information system. But it is a human given examination number and not constant for one patient over several examinations.

Much lower is the interoperability for equipment, generator function and contrast agent data. The presence of these data varied from vendor to vendor very much. Applications, that decode and interpret these data cannot expect these data to be present in all received datasets.

The date and time information were of very inconsistent quality and could poorly be used for time synchronization [5]. This might be caused by the very high number of time stamps in the DICOM standard, that can be used within image objects. For time synchronization, the attribute pair 'acquisition date/time' is of most importance, because it describes the exact moment of image data acquisition. In contrast, the attributes 'content date/time' describe the moment the physician started the data acquisition. It was shown, that only one vendor encoded both attribute pairs, but with the same information.

One vendor did not use any of these attributes, although 'content date/time' is a type 2C attribute with a fulfilled condition. This is a good example for the difficulties in pure DICOM validation. The validation tool first needs to check the conditions. In this situation the condition is a clinical context ('image data are temporarily related'), which cannot be tested automatically. Even if the vendor would include these attributes but encode an empty string, the DICOM conformity would be given. But it would of course not enhance system interoperability, because clinical information is still missing.

The reason for this paradox can be found in the large number of type 2 attributes. These attributes must be present in a dataset, but can be encoded with zero length. For clinical communication it is necessary, that data always can be found at a defined position. On the other hand a lot of old systems cannot deliver all possible data, that are included in the object definition.

A relevant finding is, that in order to enhance interoperability, the reliable presence of type 2 attributes must be increased in future. In part this already happens. With an improved internal communication between X-ray generator, gantry, image processor and DICOM interface of acquisition systems, the number of encoded values will be growing.

The presence or absence of the attributes might be documented in the conformance statement, that the manufacturer creates for each piece of equipment. In some cases however, the conformance statements did not contain these information and in others the documentation did not fit to the implementation. The quality of conformance statements must also be enhanced

significantly in future.

On the other hand, the very technical conformance statements are not intended to be read and understood by the physicians. In addition, documents should be offered for customers, that describe DICOM compliance in a less technical way.

An additional approach would be to define 'extended' DICOM modules like 'equipment data' or 'generator data' or 'time synchronization', that include the presence of certain type 2 attribute contents. The vendors could claim the 'extended' DICOM compliance and use it as a marketing tool. It is absolutely important, that these 'extended modules' are downwards compatible and fit to the basic modules, otherwise this would lead to a multiplicity of standards.

## 6. Conclusion

The angiographic image object allows the encoding of a large number of clinical helpful values. Most of them are not or only partially used. The most reliable quality was found for data, that are closely related to image data. This is easy to explain, because DICOM was is basically developed and is used to exchange image data. But DICOM can do much more. It is possible to store unique patient and examination ID's, encode exact acquisition date and time information to enable synchronized multi-modality display etc. All these features cannot be used in daily practice until a large number of datasets did not contain the required data.

The usage or current non-usage is not caused by limited DICOM compliance. For practical reasons DICOM needed to set the minimal requirements as low as possible. On the other hand new systems have been developed in meantime, that can export much more of these usable information.

It can also be concluded, that DICOM validation alone is not sufficient to estimate interoperability. Automatic validation mostly ignores the values of contents and can only perform plausibility testing. For interoperability testing the usage of attributes in different datasets must be compared in addition. This requires a semi-automatic approach, that includes both automatic basic compliance testing and manual reviewing with expert knowledge.

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