Which media are most likely to solve the archival problem?

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Abstract

The clinical application of quantitative methods for coronary arteriography remains limited, due in large part to the absence of a suitable replacement for cinefilm as the procedure record. The extension to the clinical environment of the validated objective methods which have found such widespread acceptance in clinical research studies is difficult to implement if the time-consuming and variable process for digitization of selected cinefilm frames is required. In addition, the complete integration of the angiographic procedure record with other patient records and procedures stored in a digital data format requires that the angiographic data eventually be converted to a digital format as well. Replacement of cinefilm requires that the media chosen for the task provide at least the same capabilities and preferably improved functions as those provided by cinefilm as a display, transport, and archival media. The demanding set of requirements imposed on the replacement options include high capacity, high acquisition rate, high transfer rate, application in a distributed environment, portability between institutions, and low expense. A true digital solution should also provide immediate access to the results of the angiographic procedure, transfer of image data over digital networks, multiple-user viewing capability, and quantitative analysis on a routine basis for all patients. In fact, a single media may not provide all the capabilities listed above but, rather, different media may need to be used for specialized tasks, i.e. the solution for archival may not be the same that will be employed as the portable patient record. Separation of the archival function from the acquisition/display and portable transfer functions increases the likelihood that cinefilm can be replaced in the imminent future by reducing the demands on a single media. Among the archival options available today are: (1) magnetic disks; (2) analog laser optical disks; (3) digital laser optical disks; (4) digital file-based magnetic tape; (5) digital video magnetic tape. In evaluating each of these alternatives, an accounting is required of how each meets the archival requirements along with an approximate breakdown of cost and readiness for implementation as a clinical solution today.

Introduction

The elimination of 35 mm cinearteriographic film as the recording and archiving medium for coronary arteriographic procedures has been imminent for nearly a decade, since the introduction of digital angiographic techniques [1,2]. It soon became evident, however, that the existence alone of digital angiographic technology was not sufficient to supplant cinefilm as the permanent patient record due to both technical as well as economic reasons. Early implementations of digital angiography did not meet the necessary acquisition and display requirements and, until recently, the cost for providing the capabilities required to record the dynamic information produced in contrast arteriography and ventriculography made replacement of cinefilm prohibitive. Nonetheless, the desire to find ‘something better’ than cinefilm grows among cardiologists, technicians, hospital administrators, and researchers [3]. The replacement of cinefilm has remained an elusive goal due to the fact that the performance requirements to which we have become accustomed are quite demanding when compared to the needs of other digital technology such as the storage of computer data. These requirements include high-speed acquisition and display capability, high storage capacity, portability of
data, and low cost. The task is further complicated by the desire to utilize the data in a digital format, allowing the integration of the patient angiographic record with the hospital information system (HIS) [4], transport of images over computer networks, and the application of quantitative analytical methods [5].

Among the obstacles to the replacement of cinefilm is the failure to define clearly and to separate the functions it provides, e.g. acquisition and/or display versus image archival. As a result, the task has been made more difficult than might otherwise be possible since it may be possible to provide all the functional requirements through the use of several media. While this may not be the most elegant way to achieve the desired goals, it does increase the probability that the functions listed above are provided in the near future and at an economical cost. For the purposes of this paper, therefore, the means for archival of cardiac angiographic data will be treated as a separate function from the other capabilities of cinefilm. This issue will be emphasized below as each of the potential replacements for cinefilm are discussed so that readers may decide for themselves which functions are most desirable to them and, in turn, which media are most suitable for their needs.

Requirements for a cine replacement

Performance requirements

The basic requirements that must be met by any media which is to replace cinefilm as the patient record in the cardiac catheterization laboratory have been established as a result of over thirty years of everyday use in a variety of clinical environments [6].

High rate of acquisition

Images are acquired during a cardiac catheterization procedure at rates of 15 to 60 frames/s, with 30 frames/s being common. Since most observers agree that the minimum equivalent resolution required corresponds to an image matrix of $512 \times 512 \times 8$ bits [7], this corresponds to an acquisition rate of 7.5 Mbytes/s but could be as high as 60 Mbytes/s (if a matrix size of $1024 \times 1024$ and an acquisition rate of 60 frames/s is employed). While, for most purposes, the smaller image matrix is clinically acceptable, there is increasing availability of the higher resolution matrix with its accompanying higher technical demands.

Large storage capacity

The total amount of data required to store a single procedure corresponds to 50–100 seconds of images or approximately 600 Mbytes of digital data but this may be as high as 3000 Mbytes if the higher resolution matrix is employed. A patient volume of approximately 1500 examinations annually per laboratory would lead to a total storage need of 900 Gbytes per laboratory per year. In a large institution with multiple labs, such as the situation at Duke University with an annual volume of 7000 patients, this requires a minimum of 4200 Gbytes of data per year. The requirement to have ready access to patients’ data for some 5–10 years means that a total of anywhere from 500 Gbytes (for a small-volume laboratory) to 42,000 Gbytes of storage must be provided. While an archive system needs to be expandable to handle the large amount of data accumulated over periods of up to ten years, a single piece of media must hold at least an entire patient’s exam or approximately 1 Gbyte without loss of information.

Dynamic display of images

Among the most important of its attributes, cinefilm provides the continuous display required for diagnosis of cardiovascular disease. The detection of abnormalities in ventricular function and detection of coronary artery stenoses require real-time display, i.e. at the same rate as that used for the acquisition. In digital terms, this translates to the same value of 7.5–30 Mbytes/s as mentioned above. The cinefilm projectors and viewers currently used to provide this function also provide real-time direction changes, rapid magnification, and brightness adjustment.

Portability of images

Probably the most valuable capability possessed by cinefilm is its portability between institutions. The widespread availability and standardized use of cinefilm viewers makes it straightforward to transfer angiographic data among institutions, for example when a patient is referred to other hospitals for surgery or interventional procedures. The cinefilm record is also transferred from the acquisition laboratories to central analysis laboratories in the many multi-center clinical trials used to evaluate new technologies and therapies. Any media which is to be employed for data interchange should utilize a similar degree of standardization. An archive system which is to be utilized within a hospital need only have the capability for conversion of data to a format suitable for interchange.