

OncoView™ Image Management and Storage Solution: A White Paper on Managing and Storing Images in Oncology

TABLE OF CONTENTS

Introduction	1
Communications	2
Leveraging existing infrastructure	
Connecting with the enterprise	
Serving the referring community	
Storage	5
Reliability	
High data availability	
Simplified management	
Conclusion	10
Glossary	11

Introduction

Radiation oncology is in the middle of a dramatic transformation driving an exponential growth in the size, complexity, and quantity of images generated during the treatment process. The success of image-guided oncology programs means that new images are generated at each step in the treatment process, such as diagnosis, staging, planning, verification, setup, response, and follow-up. Storing, managing, and accessing these images over the long term is critical as the gigabytes of today give way to the terabytes and petabytes of the future.

In oncology, image utilization is increasing for techniques such as intensity-modulated radiation therapy (IMRT), image-guided radiation therapy (IGRT), DART™ dynamic adaptive radiation therapy using cone-beam CT (CBCT). Traditionally, much of this electronic data has been stored in proprietary closed systems that frustrate inter-departmental communication. By adopting industry standards such as DICOM and HL7, an oncology department can improve bidirectional communication with other departments in the hospital system. Standardization of healthcare environments is supported by initiatives — such as Integrating the Healthcare Enterprise (IHE), a program from the HealthCare Information and Management Systems Society (HIMSS) and the Radiological Society of North America (RSNA) — that aim to establish common protocols for integrating hospital imaging and information systems.

The OncoView™ image management and storage solution is Varian Medical Systems' version of an oncology-specific PACS. OncoView includes the proven technology from XStor Medical Systems for reliable, industry-standard storage management. OncoView provides oncology departments with a scalable, integrated, image storage solution with the XStor Storage Appliance. The XStor Storage Appliance is a cost-effective, reliable, and scalable solution with advanced features such as online checksums, snapshots, and non-disruptive storage expansion. While studies have shown that data management costs three to seven times the initial acquisition cost¹ and that as the disk size grows, the probability of data corruption increases², high cost and poor reliability are not inevitable. This paper describes the how Varian's OncoView offers reliable, scalable, and cost-effective access to your imaging data.

1 Galen Schreck with Charles Rutstein and Steven Kim. (2001.) *Slaying the Storage Beast*. Forrester Research.

2 Lakshmi N. Bairavasundaram, Garth R. Goodson, Shankar Pasupathy, and Jiri Schindler. (2007.) *An Analysis of Latent Sector Errors in Disk Drives*. *Proceedings of the 2007 ACM SIGMETRICS International Conference on Measurement and Modeling of Computer Systems*.

Communications

Varian's OncoView is based on the Oncology Imaging System Platform, which relies on open standards. The use of open standards means that many medical devices can connect to OncoView, making the oncology department more integrated with the hospital IT ecosystem.

Leveraging existing infrastructure

Using existing PACS for storage

Varian's OncoView leverages a hospital's significant investments in medical imaging infrastructure by storing some or all of the Oncology image data in the hospital image storage system. OncoView can parse image data and route selected data types into the hospital PACS while storing the rest of the data internally. For example, if the existing PACS manages CT or PET images but not DICOM RT structure sets, then OncoView can store DICOM RT structures and forward CT and PET studies to the hospital PACS. Additionally, OncoView will keep track of the forwarded studies and can recall them when they are needed for oncology. Moreover, a brokered solution reduces system configuration effort by routing access to the hospital PACS through the server rather than through connections from every workstation that accesses the data.

Discovery of data in third-party imaging systems

The OncoView™ image management and storage solution can periodically query other PACS devices to discover patient information residing in the other PACS. On a configurable periodic schedule, OncoView can go out to another PACS to query for information for a given patient list. The data discovery function acts like a targeted crawler that uses an active patient list from OncoView. Typically, the active patient list consists of patients accessed recently, and patients still undergoing treatment. Using an active patient list minimizes network traffic by ensuring only relevant queries are executed.

Connecting with the enterprise

Using an enterprise master patient index

The OncoView™ image management and storage solution has an optional enterprise master patient index (EMPI) system to ensure that it contains clean and up-to-date demographic data from a reconciled patient record. Consistent with Varian's open-system philosophy, OncoView will also connect to existing hospital EMPI systems using HL7. OncoView registers its patient record with the EMPI so that other hospital information systems can reconcile their patient identification information with that of the oncology department.

Inbound HL7 communications: Patient demographics

Patient demographic updates from the hospital's enterprise system can be sent to the oncology department via HL7 allowing OncoView to use the same individual patient identifiers that are used throughout the hospital. OncoView can handle patient demographic updates in various ways. For example, the system can update the patient record in its database tables without updating the data in the headers of the files. A web-based user interface allows the system administrator to easily make updates to these policies.

Inbound HL7 communications: Scheduling

OncoView will be able to receive information from departmental scheduling systems to support the most effective data flow and workflow. The system would then take action based on the status of the patient and the type of visit scheduled. For example, OncoView could be configured to pre-fetch a patient's imaging studies from the hospital PACS the night before his planning CT scan appointment. The pre-fetched studies would then be available for use in OncoView, and could even be pushed to a particular workstation in advance to streamline the planning workflow for the oncologist and physicist.

Serving the referring community

Outbound HL7 communications: Oncology reports to EHR

Not only does the OncoView™ image management and storage solution accept and use information from other systems on the hospital network, it will also be able to export data to an electronic health record (EHR) through an HL7 interface.

Ultimately, information such as status, organs at risk, and dose information can be sent to the EHR. This capability will serve the referring community by giving them insight into what is happening with their patients via a familiar EHR interface.

Web-based access for referring community

By allowing the referring community read-only access to the web server, tracking patient treatments and health status would be faster and more efficient. This interface could be linked to another hospital information system (HIS) interface for ease of reference. Security on this interface could be managed via individual logins, or by a single HIS-level credential that would allow the HIS to take responsibility for authentication, authorization, and auditing.

Information included in this interface is more substantial than the information that would be sent to an EHR via HL7, and it is displayed in a more structured way, which helps users identify the information they seek.

Storage

The XStor Storage Appliance is a scalable, cost-effective storage solution with built-in, enterprise-class features such as online checksums, RAID 6, hot spares, snapshots, and continuous data protection. Simplified management of data storage, along with robust monitoring and notifications, make the appliance best-in-class in terms of reliability, availability, and serviceability. This section presents the details of this next-generation storage appliance.

Reliability

As disk sizes grow larger, the chances of downtime due to disk corruption increase. The XStor Storage Appliance uses multiple mechanisms to ensure application data integrity, data protection, and high availability.

RAID 6 protection

High-performance RAID 6 provides data availability even with the loss of any two disks in the appliance. A RAID 6 array requires at least four disks. In this minimal configuration, data is written on two disks and two different parities—a simple XOR parity (P1) and Reed Solomon code parity (P2)—which can be used to reconstruct the data written on the other two disks. In practice, RAID 6 array typically contains five to twelve disks. The data and the parity are striped across disks for maximum performance and reliability. The RAID 6 implementation is illustrated in figure 1.

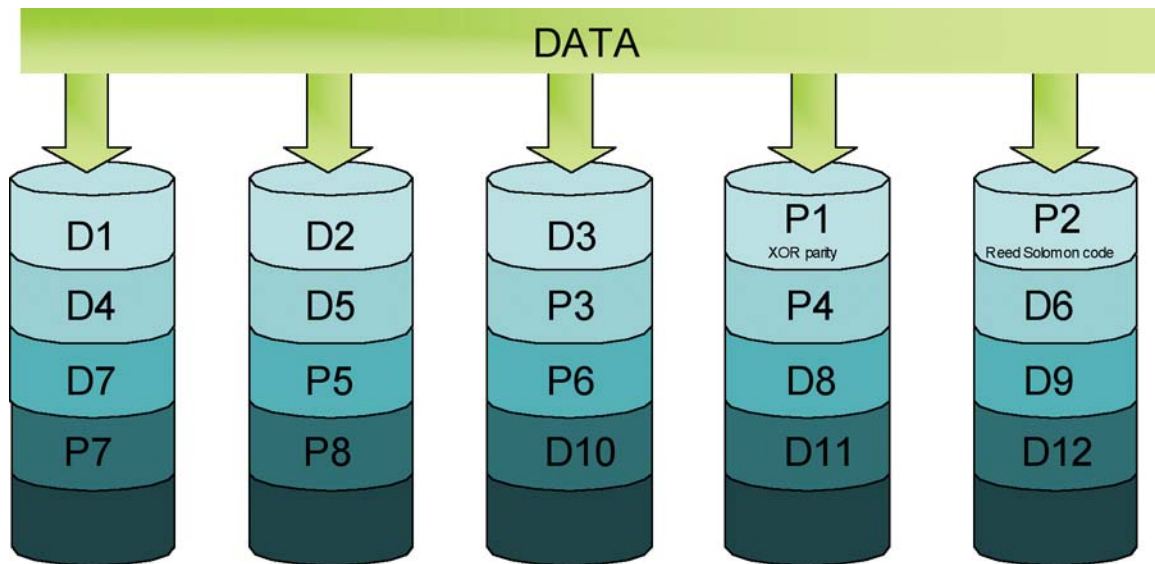


Figure 1. RAID 6 data distribution using double parity

Write-hole protection

In traditional RAID 5 implementations, there is no guarantee that data and the corresponding parity will be written in an atomic fashion. (Atomicity is a property that guarantees an operation to occur completely or not at all.) Without this guarantee, silent data corruption can occur on disk. For example, the data could have been written on one disk and, for various reasons (e.g., power failure), the corresponding parity may not have been written to the disk. If such corruption were not detected or repaired before disk failure, loss of data would occur. The worst-case scenario would occur if the disk with the data or parity failed, the RAID reconstruction process wrote erroneous data in the parity or data disk, and the error was not detected at all, causing silent data corruption.

The XStor Storage Appliance's underlying RAID mechanism uses transactions to write data on disk. By guaranteeing the atomicity of the writes of both the disk and parity, there is no write hole or possibility of silent data corruption.

Online checksums

Write-hole data corruption is only one example of how silent data corruption can occur. Errors in memory, controllers, disk firmware, or in any other component along the data path can also cause silent data corruption. The XStor Storage Appliance uses checksums to ensure data consistency at all times. Checksums are written as a header along with the data using the transaction mechanism. When data is read back, it is compared with the checksum written to ensure that the file system is reading the same data it wrote.

High data availability

The reliability features in the XStor Storage Appliance are enhanced by the high-performance and management features described below.

Continuous data protection

OncoView, the imaging database, and the DICOM images must be in sync during snapshot and back-up operations to protect critical imaging data. The storage appliance communicates with the OncoView application in order to take consistent snapshots. Snapshots can be taken at critical points, such as at the end of a patient archive operation, or before and after system upgrades.

Nondisruptive storage expansion

Storage can be added online without any data access disruption by adding disks to the storage array. The storage capacity is expanded automatically, and becomes immediately available to applications.

Snapshots

Snapshots can be event-based or can be configured to be taken at predetermined time intervals. Any number of instantaneous snapshots can be taken without disrupting access to data. The use of snapshots provides rapid recovery in case of operator or application error, ensuring high availability of data to users.

Hot spares

In addition to RAID 6 protection, hot spares ensure that RAID operates at an optimal state as quickly as possible in the event of disk failure.

The process of hot spare activation is illustrated in figure 2.

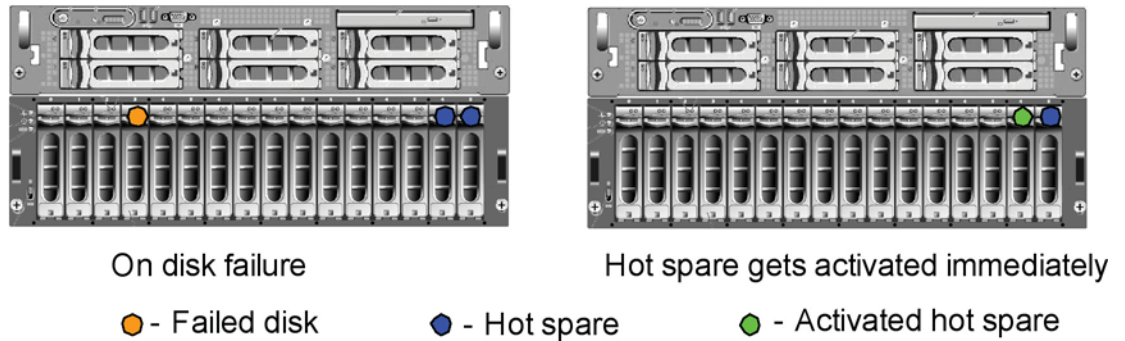


Figure 2. Hot spare activation

Hot spares provide a predictable maintenance and service schedule for system administrators. Administrators can replace failed disks at pre-scheduled times or at their convenience to ensure that the system is operating in its optimal state.

Fast rebuild

When a disk fails in a RAID configuration, the system is in degraded mode until the data is reconstructed on a hot spare or a replacement disk. The XStor Storage Appliance minimizes the time taken to rebuild the replacement disk by copying over only the content. Current RAID systems rebuild the entire disk, independent of content to reach an optimal state. This operation can take hours, as disk capacities can reach the terabyte range. With the XStor Storage Appliance, however, the time taken to rebuild is dependent on the used space on the disk rather than on the size of the disk. The file system keeps track of the content present on each disk; on rebuild, the file system uses this knowledge to copy over only the lost content. Reduced rebuild time improves data availability because an optimal state is reached as quickly as possible.

Guaranteed on-disk file system consistency

With a copy-on-write mechanism in the XStor Storage Appliance, the on-disk data is always consistent. This means that, even in the case of a power failure or unclean shutdown, wait times for system availability are reduced. In contrast, conventional systems evaluate entire disk structure to ensure file system consistency. When file system capacity trends toward multi-terabyte, it can take hours, if not days, for conventional systems to become available. Because no guarantee for on-disk file system consistency exists with conventional systems, it is possible for the file system to become unavailable, even after waiting for the check to complete.

Self-healing

Checksums, in combination with RAID 6, provide self-healing in case of data corruption. On detection of checksum errors, data is read from other disks to repair the corrupted data. High data availability is provided by self-correction of data, even if data on one disk is corrupted.

Simplified and remote management

The XStor Storage Appliance is designed from the bottom up for simplified management. Built-in remote management capabilities allow problem diagnosis, remote fixes, and software upgrades to be performed from a central service center. Web-based management tools allow storage expansion, network share, quota management, system monitoring, policy setting, and remote fixes from any secure location. This results in significant cost savings, as in-house personnel can focus on revenue generation rather than servicing the storage appliance. Replacement parts can be sent to the installation site upon detection of any component failure, thereby allowing remote service of the product.

Dynamic partitioning

The total storage capacity can be shared among multiple network shares without the need to partition the storage. This improves the storage utilization, as each share uses the space it needs and the rest is available for other network shares. If necessary, shares can be assigned to a minimum space quota to ensure that they can operate normally. These quotas can be dynamically resized as requirements change.

Monitoring and notifications

The appliance is constantly monitored to ensure that any degradation in system operation can be quickly brought to notice based on rules established by the system administrator. Notifications can be sent via email, SMS, pager, and RSS feeds. The graphical user interface (GUI) displays the error condition, the criticality, and the recovery procedure in cases where system maintenance is required.

Comparison with conventional systems

Table 1 shows the summary of features compared with conventional network-attached storage (NAS) systems.

Feature	XStor Storage Appliance	Conventional NAS
Network Accessible Storage (CIFS)	✓	✓
Appliance Monitoring	✓	✓
Web-based Management	✓	✓
Hot Spares	✓	✓
Application Aware Storage	✓	X
Snapshots	✓	X
Protection Against Dual Disk Failure	✓	X
Online Expansion	✓	X
Data Integrity through End-to-end Checksums	✓	X
Self-healing in Case of Data Corruption	✓	X
Remote Monitoring from Central Service Center	✓	X

Table 1. Comparison of XStor Storage Appliance with conventional NAS

Conclusion

The technologies used in the OncoView™ image management and storage solution implement some of the most powerful features available today. The result is a robust, scalable, secure solution that extends the reach of the oncology department within the hospital.

OncoView opens the oncology department to the rest of the hospital ecosystem by:

- Providing inbound and outbound DICOM interfaces
- Providing inbound and outbound HL7 interfaces
- Connecting to an EMPI
- Making a web interface available to the referring community

Secure access to the system ensures compliance with HIPAA and other hospital IT policies.

OncoView with the XStor Storage Appliance utilizes next-generation technologies and provides a scalable storage solution with simplified management and high data availability features. The maintenance and service costs of the appliance are kept to a minimum through the use of the following features:

- Continuous data protection
- RAID 6
- Write-hole protection
- Online checksums
- Hot spares
- Snapshots
- Self-healing
- Dynamic partitioning
- Fast rebuild
- Guaranteed on-disk file system data consistency
- Monitoring and notifications
- Remote management

All of these enterprise-class features are provided using industry-standard hardware for a cost-effective solution.

Glossary

Acronym	Definition
CBCT	Cone-beam computed tomography
CIFS	Common internet file system
CT	Computed tomography
DART	Dynamic adaptive radiation therapy
DICOM	Digital Imaging and Communications in Medicine
EHR	Electronic health record
EMPI	Enterprise master patient index
EMR	Electronic medical record
GUI	Graphical user interface
HIMSS	HealthCare Information and Management Systems Society
HIS	Hospital information system
HL7	Health Level 7
IGRT	Image-guided radiation therapy
IHE	Integrating the Healthcare Enterprise initiative
IMRT	Intensity-modulated radiation therapy
IT	Information technology
NAS	Network-attached storage
PACS	Picture archiving and communication system
PET	Positron emission tomography
RAID	Redundant array of independent disks
RAID 6	Redundant array of independent disks with double parity protection
RSNA	Radiological Society of North America
RSS	Really simple syndication
SMS	Short message service
XOR	eXclusive OR

Varian Medical Systems Oncology Systems

3100 Hansen Way
Palo Alto, CA 94304-1038
Tel: 650.424.5700 | Tel: 800.544.4636
<http://www.varian.com>

USA Headquarters

California

Varian Medical Systems
Palo Alto, CA
Tel: 650.424.5700
800.544.4636
Fax: 650.493.5637
www.varian.com

USA Regional Offices

California

Varian Medical Systems
Corona, CA
Tel: 951.280.4401
Fax: 951.280.4300

Georgia

Varian Medical Systems
Marietta, GA
Tel: 770.955.1367
Fax: 678.255.3850

Illinois

Varian Medical Systems
Des Plaines, IL
Tel: 847.321.6810
Fax: 847.321.6811

New Jersey

Varian Medical Systems
Clark, NJ
Tel: 732.340.9346
Fax: 732.381.1060

European Headquarters

Switzerland

Varian Medical Systems
International AG
Zug, Switzerland
Tel: 41.41.749.8844
Fax: 41.41.740.3340

Austria

Varian Medical Systems
Gesellschaft m.b.H.
Voessendorf, Austria
Tel: 43.1.698.56.56
Fax: 43.1.698.56.59

Belgium

Varian Medical Systems
Belgium N.V./S.A.
Diegem, Belgium
Tel: 32.2.720.10.08
Fax: 32.2.720.77.07

Finland

Varian Medical Systems
Finland Oy
Helsinki, Finland
Tel: 358.9.430.771
Fax: 358.9.455.4585

France

Varian Medical Systems France
Buc, France
Tel: 33.1.30.83.83.83
Fax: 33.1.30.83.83.00

Germany

Varian Medical Systems
Deutschland GmbH
Darmstadt, Germany
Tel: 49.61.51.73130
Fax: 49.61.51.731313

India

Varian Medical Systems
India Pvt Ltd.
Mumbai, India
Tel: 91.22.26162301
Fax: 91.22.26162277

Varian Medical Systems
India Pvt Ltd.
Chennai, India
Tel: 91.44.28295970
Fax: 91.44.28295980

Italy

Varian Medical Systems
Italia, S.p.A.
Cernusco s/N (MI), Italy
Tel: 39.02.921.351
Fax: 39.02.921.35240

Netherlands

Varian Medical Systems
Nederland B.V.
Houten, Netherlands
Tel: 31.30.634.0506
Fax: 31.30.636.2466

Scandinavia

Varian Medical Systems
Scandinavia AS
Herlev, Denmark
Tel: 45.44.500.100
Fax: 45.44.500.190

Spain/Portugal

Varian Medical Systems
Ibérica, S.L.
Madrid, Spain
Tel: 34.91.33.44.800
Fax: 34.91.33.44.801

UK/Ireland

Varian Medical Systems
UK Ltd.
Crawley, West Sussex, UK
Tel: 44.1293.601.200
Fax: 44.1293.510.260

Asian Headquarters

Hong Kong

Varian Medical Systems
Pacific, Inc.
Kowloon, Hong Kong
Tel: 85.22.724.2836
Fax: 85.22.369.4280

China

Varian Medical Systems
China Ltd.
Beijing, P.R. China
Tel: 8610.6512.7169
Fax: 8610.6523.2039

Japan

Varian Medical Systems K.K.
Chuo-ku, Tokyo, Japan
Tel: 81.3.3639.9700
Fax: 81.3.3639.9623

Latin American Headquarters

Florida

Varian Medical Systems
Miami, FL USA
Tel: 305.929.1970
Fax: 305.929.1971

Brazil

Varian Medical Systems
do Brasil Ltda.
São Paulo, Brazil
Tel: 55.11.3457.2655
Fax: 55.11.3286.0034

Australian Headquarters

Australia

Varian Medical Systems
Australasia Pty Ltd.
Sydney, Australia
Tel: 61.2.9485.0111
Fax: 61.2.9485.0119

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