Theses Digitization Project   John M. Pfau Library

2002

Curriculum guide to teach computed radiography at El Camino College

Dawn Nella Guzman

Recommended Citation

Guzman, Dawn Nella, "Curriculum guide to teach computed radiography at El Camino College" (2002).
Theses Digitization Project. 2147.
https://scholarworks.lib.csusb.edu/etd-project/2147

CURRICULUM GUIDE TO TEACH COMPUTED RADIOGRAPHY

AT EL CAMINO COLLEGE

_____

A Project

Presented to. the

Faculty of

California State University,

San Bernardino

_____

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Education:

Career and Technical Education

_____

by

Dawn Nella Guzman

June 2002

CURRICULUM GUIDE TO TEACH COMPUTED RADIOGRAPHY

AT EL CAMINO COLLEGE

A Project

Presented to the

Faculty of

California State University,

San Bernardino

----

by

Dawn Nella Guzman

June 2002

Approved by:

Joseph A. Scarcella, Ph.D., First Reader   5/29/02
                                                  Date

Ronald K. Pendleton, Ph.D., Second Reader

ABSTRACT

During the past decade, the profession of radiologic technology has seen rapid changes. New evolving technologies have significantly impacted not only on the practicing radiologic technologist, but also the educators, administrators, and students in the radiologic sciences. This results in a limited number of qualified radiologic technology professionals who are proficient in the new technology.

As of this writing, there was no curriculum available on these new technologies in a concise format. Therefore, each educator has been forced to research many sources and develop their own curriculum.

The purpose of the project was to design a curriculum guideline for educators to teach computed radiography. This project can be used as a stand-alone course, or integrated into existing radiologic technology courses. This project was developed through research of many technical resources and collaboration with experts in the field. The results have helped the educators to become proficient with the new technology, and better prepare students and technologists for the imaging of the future.

ACKNOWLEDGMENTS

There are many people to whom I am eternally grateful for their help, encouragement, advice and support along my journey.

The excellent faculty and friends that I have encountered at California State University, San Bernardino, who have made a significant impact on my education and self-esteem: Dr. Ronald K. Pendelton, Dr. Joseph Scarcella, Dr. Deborah Stine, Mr. Timothy Thelander, and Ms. Lorie Suntree. Thank you for believing in me, and recognizing a greater potential in me than I could in myself. I will always remember you.

For the much needed technical advice, contributions and support, I would like to thank: Mr. Donald Visintainer, Radiologic Technology Program Director at El Camino College, Mr. Rolly Reyes, Educator at El Camino College, and Ms. Kathryn Kneeburg, Eastman Kodak Company Applications Specialist.

Thank you to my wonderful family and friends, for your endless patience and sacrifices during my absences. Especially, my two sons, Adam and Eric, who endured many frozen dinners and fast foods so mom could study and write. To Dad and Becky, Linda, Joe, Howard, and Andrea, each of you holds a special place in my heart.

DEDICATION

There are so many special people who have had such a tremendous impact on my life, my education and my career. Mere words cannot express the depth of my gratitude and love. I dedicate this to you:

To: H.C., you supported me, comforted me, pushed and encouraged me, but most of all you showed faith in me and taught me how to believe in myself. Thank you for your persistence and for being my friend.

To: L.B., you have been there for me always, and in any situation, and you listened. You're the best friend anyone could ever ask for. Thank you.

To J.C., who mentored me and showed me that when one door closes, another will open. Thank you for helping me grow.

To: D.J.V., Since the inception of my career, you were there to guide me in the right direction. Now as I seek to attain higher goals, you are again here to guide me. I admire your example and dedication to our profession and to our students. Your help and support has brought me to where I am today. You have been a great mentor and model for me. Thank you.

TABLE OF CONTENTS

CHAPTER ONE

BACKGROUND

Introduction

The content of Chapter One presented an overview of
the project, which addressed the need for a standardized,
simplified, and concise curriculum guideline to teach
computed and digital radiography, also known electronic
imaging. The context of the problem was discussed followed
by the purpose, significance of the project, and
assumptions. Next, the limitations and delimitations that
apply to this project were reviewed. Finally, a definition
of terms was presented.

Context of the Problem

During the past decade, the profession of radiologic
technology has seen rapid changes. New imaging equipment,
techniques and procedures have contributed to increased
professional demands in the workplace. These changes have
significantly impacted not only the practicing radiologic
technologist, but also the educators, clinical
instructors, managers, administrators and students in the
radiologic sciences (Clark and Geotz, 1996).

The rate at which diagnostic imaging procedures are
performed continues to accelerate, while the number of

qualified radiologic technology professionals to perform these procedures continues to decline. As the technology evolves, radiology department managers are desperately looking for more efficient means to handle the new equipment, increased patient flow and staffing shortages, while radiologic technology program directors actively market their programs to increase student enrollment (Eubanks, 1999).

Enrollment in Health Care programs throughout the country has steadily declined since 1995. Shortages in nursing are highly publicized due to the sheer number of nurses, and immediate impact on patient care. In actual percentages, however, there is a greater shortage of qualified radiologic technologists (17%) than in the nursing profession [11%] (Department of Health and Human Services Statistics [DHHSS], 2001).

Three levels of educational programs exist in radiologic technology: certificate programs operated by hospitals; associate degree programs offered by junior and community colleges, technical-vocational schools and four year colleges and universities; and baccalaureate degree programs offered by four-year colleges and universities. Graduates from the three program levels may perform the same tasks and often are fixed at the same rate of pay.

Also, graduates of accredited programs at any level are eligible to take the certification examination administered by the American Registry of Radiologic Technologists [ARRT].

In the state of California, there are currently over 23,000 certified radiologic technologist (DHHSS, 2001). Nationally, there are over 225,000 registered radiologic technologists in practice (ARRT, 2001). There are 31 Radiologic Technology Schools in California, 25 of which are community college or university-based programs, and 6 are hospital-based programs (Radiologic Technology Educators of California [RTEC], 2001). With an average of 20 students per year/per program, this accounts for approximately 750 radiologic technology students in California during any given year. Nationally, there are over 8,000 students graduating from Radiologic Technology Programs annually (ARRT, 2002). Only a small percentage of these professionals (educators and students) have any background education in the emerging computed radiographic technology and applications (Fay, 2000).

Recent acquisition of these new computed imaging technologies in many medical imaging departments throughout the country, have left radiographers and managers alike, scrambling to become proficient in the use

and operation of this equipment. After installation of the equipment is complete, most vendors send an applications specialist to orientate the staff in the use and operation of this new equipment (K. Kneeburg, personal communication, April 20. 2001). Unfortunately, the training these radiographers receive is cursory at best. Due to time availability, staffing shortages, increased patient and procedure loads, and cost constraints, there is often a tremendous void left in the area of training the radiographer to acquire the basic concepts and theories of operation of the new equipment and technology. This leaves many technologist feeling frustrated and resistant to change. This, in effect, returns these professionals to a state of "button pushing", something that the profession has worked long and hard to move away from. This also leaves the student radiographers, who are training under these technologists, with a sense of confusion and skepticism. The technologists lack the knowledge to explain the concepts, leaving the student's clinical training compromised and inadequate.

In November of 2001 the American Society of Radiologic Technologists (ASRT) published a curriculum draft to cover the content standards for the practice of diagnostic radiography as outlined by the American

4

Registry of Radiologic Technologist (ARRT). This was the first formal curriculum guideline ever officially produced for the radiologic sciences. Although, a step in the right direction, this document is over 100 pages in length, and does not offer any additional information such as lesson plans, lecture notes, support documentation or resource information. In other words, it provides lists on what should be taught, but it does not provide how or where to find the background information on the various subjects. Mingled in throughout this document are limited references to electronic imaging. At the time of this writing, there was not a simplified, but comprehensive curriculum guide containing information on computer radiography that would enable an educator, student radiographer, or working technologist to master these new modalities. The theory and practical application of computed radiography must be integrated into the educational and real-life "hand-on application" environments via a contextual learning model (Weinbaum & Rogers, 1995).

Many of the radiologic technologists working in the field, as well as, the educators who are responsible for teaching the students entering this profession, have little or no previous experience in the area of computed and digital radiography. All accredited radiography

programs provide formal training in radiation physics and protection, equipment operation and maintenance, and image production, as set forth by the professional standards of the ARRT. As of yet, there has not been a single "how to" handbook published for teaching the new technology. This problem is complicated by the limited amount of information made available from the State of California, Department of Health Services, Radiologic Health Branch [DHS-RHB] or the ARRT on specifically how much, or what to teach. Each instructor is required to research and draw information, (usually very "technical" in nature), from any resource available, and as a result, they are forced to create their own curriculum. Each program's content varies with the skill and experience of the instructor (Finch & Crunkilton, 1999). Because a standard formal curriculum on computed radiography has not been developed or made available by the state or national licensure organizations, many educators have chosen to not to teach these new modalities at this time (RTEC, 2001). The students are then at a disadvantage. This content area may be included on state and national examinations, and therefore without the exposure, the students will be less successful in passing state and national licensing examinations. It was unclear when the question was asked

to an official from the State of California, Radiologic
Health Branch (RHB) as to when this new technology may be
included in the licensing examinations (P. Scott, personal
communication, October 21, 2001). In addition, when the
students or graduates enter the workforce, they will not
be prepared sufficiently to work in medical imaging
centers that already have this equipment in place.

Going "filmless" has been the buzzword in radiology
for many years. High-speed digital computers coupled with
cheap memory and useful software permitted the widespread
use of computers for work and personal use. This
technology was rapidly developed and integrated into the
field of radiologic technology. The technology of the
future is here. To keep pace, radiologic technology
educators must implement this new technology into their
curriculum.

<div align="center">Purpose of the Project</div>

The purpose of the project is two-fold. First, to
design a curriculum guideline for educators and managers
to teach computed radiography, including digital and
direct ray technologies, to the radiologic technology
student. Secondly, the "seasoned" practicing radiographer
suddenly surrounded by this new technology has a critical

need to be trained to keep current. This curriculum could be used as a stand-alone course, or integrated into existing radiographic principles and physics courses.

This curriculum design is structured for the radiologic technology educator to facilitate the information in a contextual model for student success. Currently, El Camino College is the only community college program in the United States that offers a "hands-on" training element on computed radiography equipment in a laboratory environment on the college campus. This offers the students the opportunity to practice and apply the theory and use of this modality on simulated phantoms without risk of increased radiation exposure to actual patients.

Significance of the Project

The significance of the project is that this will be the first curriculum handbook developed for educators and managers to teach computed radiography to radiologic technology students and practicing radiographers. This curriculum will be offered through a community college. The course credits will articulate with other community colleges and state universities, as well as, apply towards continuing education credits with the ASRT for the

practicing radiologic technologist. California State University Northridge and California State University Dominguez Hills both have articulation agreements with El Camino College. This provides students who may want to transfer into a bachelors degree program, entrance into these universities at an upper graduate level.

The project will be offered to educators and managers in a simplified, but concise format to help facilitate the teaching/learning process for educators, students and practicing radiologic technologists.

Assumptions

The following assumptions were made regarding this project:

1. It was assumed that a standardized core curriculum guideline for computed and digital radiography is needed.

2. It was assumed that once the curriculum is established, it could be utilized throughout the state of California, and that it could be presented to the American Society of Radiologic Technology (ASRT) for possible adoption and integration into the nationally recognized core curriculum for radiologic technology.

Limitations and Delimitations

During the development of this project, limitations
and delimitations are noted. The limitations and
delimitations are presented in the next section.

Limitations

The following limitations apply to the project:

1. The core curriculum for computed radiography
    with digital and direct ray imaging, may be
    utilized as a standard curriculum for an
    instructor to teach this new technology at the
    El Camino College, Radiologic Technology
    Program.

2. The project is limited due to the lack of
    sufficient and easily understandable resource
    material available on curriculum development of
    computed radiography.

Delimitations

The following delimitations apply to the project:

1. The core curriculum for computed radiography
    with digital and direct ray imaging, may be
    utilized by any radiologic technology program or
    instructor to teach this new technology to
    registered radiologic technologists and students
    radiographers.

2. This curriculum is designed in a contextual
   learning model, integrating application and
   theory for the student and practicing
   radiographer.

Definition of Terms

The following terms are defined as they apply to the
project.

Allied Health Professionals - These professional health
   care providers include members from respiratory care,
   physical therapy, and radiologic technology. They are
   grouped separately from physicians and nurses, and
   are essential members of the health care team who are
   invaluable in all aspects of health care delivery
   (DHHSS, 2001).

American Society of Radiologic Technologist (ASRT) - a
   professional organization to promote professional
   development (ASRT, 2000).

American Registry of Radiologic Technologist (ARRT) -The
   ARRT is the credentialing organization that seeks to
   ensure high quality patient care in radiologic
   technology. They administer tests and certify
   technologists. They monitor continuing education and

ethics requirements for the technologist's annual
registration (ARRT, 2001).

Analog-to-digital converter (ADC) - Input device for
changing continuous (analog) signals into digital
form (Ballinger, 2001).

Authentic Assessment - can measure a student performance
and or learning within the context it was learned and
will be performed. Authentic assessment asks students
to apply their skills and knowledge in meaningful
ways (Kerka, 1995).

Carl D. Perkins Vocational Education Act - The Carl D.
Perkins Act was focused on the integration of
academic and vocational proficiencies (U.S.
Department of Education, 2000).

Certified Radiologic Technologist (CRT) - The state of
California, Department of Health Services, Radiologic
Health Branch [DHS-RHB], responsible for testing,
certification and licensure of radiologic
technologist working in the state of California
(DHHSS, 2001).

Competency-Based Education - An integrated approach to
define competence as a combination of attributes
including: knowledge, skills, and abilities.
Together, these attributes enable an individual to

fulfill a role at an appropriate level of
achievement. A competent health care provider is one
who is able to perform a clinical skill to a
satisfactory standard. Competency-based education for
radiologic technology professionals is based upon the
participant's ability to demonstrate attainment or
mastery of clinical skills performed under certain
conditions to specific standards as set forth by the
American Registry of Radiologic Technologists (ARRT).
One of the primary advantages of competency-based
education is that the focus is on the success of each
participant (Joint Review Committee on Education in
Radiologic Technology [JRCERT], 1996).

Contextual Learning - a concept of teaching and learning
that helps teachers relate subject matter content to
real world situations and motivates students to make
connections between knowledge and it's application
(U.S. Department of Education Office of Vocational
and Adult Education and the National School-to-work
Office, 1999).

Computed Radiography (CR) - Digital imaging process using
a photostimulable chemical plate for initial
acquisition of image data instead of conventional

13

film-screen cassette. A computer can manipulate the
image at a later time (Ballinger, 2001).

Curriculum – the subject matter that teachers and students
cover in their studies. It describes and specifies
the methods, structure, organization, balance and
presentation of the content (International Technology
Education Association [ITEA], 2000)

Curriculum Development – a process involving a group of
teachers writing objectives for use in their course
and, perhaps other teacher's courses (Finch &
Crunkilton, 1999).

Digital Image – An image composed of discrete pixels each
of which is characterized by a digitally represented
luminance level (Ballinger, 2001).

Digital Radiography (DR) –.This systems replaces
traditional x-ray film with reusable detectors. These
detectors are commonly divided into two types,
indirect and direct conversions. The detectors
convert incoming x-ray photons to an electronic
signal (Carlton & Adler, 2001).

Direct Conversion – Radiography systems that directly
convert incoming x-ray photons to an electronic
signal (Carlton & Adler, 2001)

14

Direct Digital Imaging - also known as direct digital

    radiography (DDR), these radiography systems use

    transistors for image capture in place of cassettes

    and convert incoming x-ray photons to an electronic

    signal for immediate viewing (Carlton & Adler, 2001).

Electronic Imaging - A broad term that applies to the new

    imaging technology incorporated into radiography

    where an analog to digital (electronic) conversion is

    involved. This includes computed radiography (CR),

    digital radiography (DR), and direct digital ray

    capture (DDR) technologies (Huang 1999).

Indirect Conversion - Radiography systems that use a two-

    part process for converting incoming x-ray photons to

    an electronic signal by first converting x-ray

    photons to light, then converting the light into an

    electronic signal. An example of this is the

    photostimuable phosphor plates used in CR (Carlton &

    Adler, 2001).

Joint Review Committee on Education in Radiologic

    Technology (JRCERT) - accredits most formal training

    programs for this field. They accredited 602

    radiography programs in 1999 (Department of Health

    and Human Services Statistics [DHHSS), 2001).

Laboratory-classroom - The formal environment in school
where the study of technology takes place. A separate
laboratory with areas for hands-on activities, as
well as group instruction, could constitute the
environment (ITEA, 2000).

Picture Archiving and Communication System (PACS) - The
development of new imaging techniques and the
increasing proportion of medical imaging modalities
that generate radiologic images in digital form for
archival, storage, and communication through high
speed telephone lines (Huang, 1999).

Radiation Dose - When a radiation exposure occurs, the
resulting ionization deposits energy in the air. This
is measured in units of Roentgen (R). If an object
such as a human body is present at the point of
exposure, energy will be deposited in that body. The
deposited energy is measured in units of radiation
absorbed dose (RAD), when the exposure is related to
a patient. If the exposure is related to occupational
workers such as radiologic technologists, the unit is
called radiation equivalent man (REM)(Bushong, 2001).

Radiologic Technologist (RT) - A professional who has been
trained and licensed in the use of ionizing radiation
to obtain images of the internal structures of the

human body, with regard to safe radiation practices.
Also known as Radiographer, Radiologic Sciences
Practitioner, and Medical Imaging Technologist (ASRT,
2001). Operates radiographic equipment to produce
radiographs (x-rays) of the body for diagnostic
purposes as directed by a Radiologists (DHHSS, 2001).

School-to-Work Opportunities Act - Signed into law in May
of 1994 by President Clinton, this act provides money
to states to develop customized programs according to
the needs of the state. There are three elements to
the law: School-based learning- high academic and
business defined skill standards; work-based
learning- career exploration, work experience,
training and mentoring at job sites; connecting
activities- integrating classroom and on-the-job
instruction, building bridges between school and work
(National School-to-work, 1996).

Secretary's Commission on Achieving Necessary Skills
(SCANS) - In 1990, the Secretary of Labor appointed a
commission to determine the skills our young people
need to succeed in the world of work. The
commission's fundamental purpose was to encourage a
high-performance economy characterized by high-skill,
high-wage employment. Members of the commission

include representative of education, business and

labor (U.S. Department of Labor, 1992).

Teleradiography - a device that enables a radiographic

image on film to be scanned, digitized and

electronically transmitted to a remote site via high-

speed telephone lines. The image is downloaded onto a

computer monitor at the offsite location for the

radiologist's interpretation (Bushong, 2001).

Organization of the Thesis

The thesis portion of the project was divided into

four chapters. Chapter One provides an introduction to the

context of the problem, purpose of the project,

significance of the project, limitations and delimitations

and definitions of terms. Chapter Two consists of a review

of relevant literature. Chapter Three documents the steps

used in developing the project. Chapter Four presents

conclusions and recommendations drawn from the development

of the project. The Appendix consists of the project:

Section A consists of the Introduction; Section B consists

of the Course Curriculum Outline for Electronic Imaging;

Section C consists of Course Curriculum guide for

computers in Radiology; Section D consists of Lesson Plans

and outlines; Section E consists of Lecture Notes and

Power Point Presentation. Lastly, the project references

follow the Appendix.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

Chapter two consists of a discussion of the relevant literature. The unavailability of clear, comprehensible, literature on the subject of computed radiography was the impetus to create this project specifically to be used by other educators and managers.

The initial literature review began a couple of years ago when the idea to incorporate this topic into the existing curriculum for radiographic principles and production arose. At that time, research produced very little in the way of printed material. The majority of information was obtained via the World Wide Web, primarily from various vendors of the products. Unfortunately, the information was highly technical and not reader-friendly; or only understandable to a small number of experts in the field. The material offered was either very superficial (in hopes of selling their product), or very technical (for use by the field engineers and computer geniuses). In any event, the need for materials useful for educating the educators, students and other users of this new technology seemed very apparent.

Initial research for this project began at the California State University, San Bernardino Phau library. An electronic search of the large database offered from the library; Nexus-Lexus, ERIC and EBSCO, to name just a few, provided much information on general curriculum development and student learning styles, but nothing specific to radiography. Two local area hospital medical libraries, the El Camino Community College library, as well as the authors own personal collection of information and materials were researched. Only a couple of textbooks that specifically covered the topic of computed and digital radiography were found. The majority of research was complied from professional journals, and the World Wide Web.

History of Radiologic Technology

The Radiologic Technologist

The delivery of high quality health care has become very complex, and it relies on a diverse team of health professionals. Some on this team – such as physicians and nurses, are familiar to the public; while others are less well known. Most of these less known providers are in a category called allied health professionals. These essential members of the health care team are invaluable

in all aspects of health care delivery. The Radiologic Technologist (RT) also known as; Radiographer, X-ray Technologist, Diagnostic Imaging Specialist and Radiologic Science Practitioner, is an integral member of this health care team. The duties of the RT include operating radiographic equipment to produce radiographs (x-rays images) of the body for diagnostic purposes. The RT positions patients on the radiographic table and adjust immobilization devices to obtain optimum views of specified areas of the body as requested by a Physician. The RT explains procedures to patients to reduce anxieties and to obtain patient cooperation. The RT moves x-ray equipment into specified positions and adjusts equipment controls to set exposure factors, based on knowledge of radiographic exposure techniques and protocols. While doing this, the RT practices radiation protection techniques using beam restrictive devices, distance, patient shields, skills and knowledge to appropriate exposure factors to minimize radiation exposure to patients, self, and staff. The RT may operate mobile x-ray equipment in operating rooms, emergency rooms or at the patient's bedside (DHHSS, 2001).

22

Discovery of X-rays

The practice and application of ionizing radiation was first discovered by accident in a laboratory in Wurtzberg, Germany in 1895. William Conrad Roentgen was a Professor of Physics experimenting with cathode ray tubes. In order to better visualize the effects of the cathode tube, he darkened the room lights. Several feet away was a photographic plate coated with a fluorescent material (barium platinocyanide), which began to glow when the tube was energized. Roentgen called this discovery "x"-ray because it was an unknown ray. The discovery of x-rays ranks high among the amazing events of human history. Other scientist had made similar discoveries, but failed to realize their significance. In 1886, Roentgen published his first x-ray image, which was obtained by placing his wife's hand between the tube and a photographic plate. A "shadow of bones" emerged, giving rise to the first application of x-rays for medical purposes. Unfortunately, the hazards of this unknown ray were not discovered until many years later, and many deaths from overexposure to radiation occurred in those early years. Roentgen's first descriptions of the properties of this mysterious ray are still accepted today (Bushong, 2001).

Processing the Image

An x-ray or film has been the common term for a radiographically produced image for many years. Before film, these images were produced on photographic glass plates. Hence, the term "flat plate of the abdomen", which is still in use today.

During World War One, the glass plates were found to be cumbersome, difficult to handle and fragile, so a cellulose type film base was invented to store the radiographic images. These films were developed much like a photograph in a darkroom. They had to be attached to metal racks then hand processed, which was extremely messy. This process could take over an hour. To save some time, films were often viewed before they were allowed to dry, leading to the term "wet read." This term became synonymous with the term "stat", which is also still used today.

Cellulose acetate was found to be highly flammable, and easily torn, which did not make for safe storage. Subsequently, a polyester base was invented, which continues to be used in films today. In the early 1970's automatic processors began to take to place of hand processing tanks. Automatic processing reduced the development time from 30 minutes to 5 minutes. Currently,

processors can develop a film in as fast as 60 seconds (Fauber, 2000). As radiology departments change to a "filmless" system, the terminology must undergo changes as well. Radiographic images on computer monitors will be common place. These changes will take a period of adjustment, especially for the seasoned technologist or physician who wants to "hold on" to that piece of film. To keep pace with this evolving technology, professionals working in the field and the general public will have to adapt to these changes (Ceaser, 1997).

Computers in Radiology

Although the properties of x-rays have not changed in the last century, the use and application have undergone tremendous changes. Particularly in the past decade. As competition in the health care industry increases and pressure mounts to streamline diagnostic workflow and increase cost efficiency, digital radiologic image acquisition, enhancement, storage and transmission technologies have become important topics for the radiologic professional. These professionals will have to become familiar with networking concepts and related issues of computerized image acquisition, storage and transmission (David, 1998).

Computed radiography (CR), digital radiography (DR),
and direct digital ray capture (DDR) technologies were
first introduced in the clinical setting in the mid
1980's. Dr. Paul Capp introduced the concept of "digital
radiology" in the early 1970's, but the technological
developments to support the requirements of digital
radiology, did not become available until the 1980's
(Huang, 1999). As with much of the computer technology,
these areas have rapidly developed into the imaging of the
present and the future.

Teleradiology and Film Digitizers

On the forefront of these technologies are
teleradiography and PACS. Teleradiography was the first
integration of an analog to digital transfer of a
radiographic image. It was introduced into medical imaging
facilities in the early 1980s. In its simplest form,
teleradiography enabled a radiographic image on film to be
scanned, digitized and electronically transmitted to a
remote site via high-speed telephone lines (Sabatini,
1999). The image could then be downloaded onto a computer
monitor at an offsite location for the radiologist's
interpretation. This also enabled radiologists to provide
interpretations from their homes, eliminating the need for
an evening "on-call" radiologist. This new technology

greatly improved health care to patients by affording earlier interpretation of images, decreasing the time for diagnosis and treatment of injuries and disease, and reducing the number of repeated radiographic exposures to the patient (Sievert, 1999). Most institutions have implemented some form of conventional film digitizer unit (PACS) into their systems. This system is at relatively low cost and only requires a purchase of the digitizer and clinical monitors (Kodak, 1996).

Filmless Radiography

Filmless radiography is the goal of every department, the solution to lost films, and reducing the need to repeat radiographic exposures to the patient, which is the key to better productivity and faster patient care. A supported picture archiving and communication system (PACS) is envisioned to streamline departmental workflow and improve efficiency (Seibert, 1999).

Computed radiography (CR) is the next step in upgrading department equipment. It is expensive, but necessary to create a "filmless" environment.

Acquiring the Image

In the past, radiographic film acted as the receiver of the x-ray beam, the viewing system of the radiographic image, and the storage device for that image. In a

filmless system, these tasks are done separately. With CR the image is captured by a special cassette which contains a plate coated with a photostimulable phosphor (PSP), a reader device with a laser beam changes the image into an electronic signal by indirect conversion, an archive system using magnetic tapes or compact disks (CD) stores the images, and a high resolution computer monitor is used to view the images. In direct digital ray (DDR), a transistor receives the x-ray beam and transforms it to an electronic signal, which is a direct conversion, and then it is sent directly to a monitor for immediate viewing, eliminating the need to any type of cassettes(Seibert, 1999). As with any new technology, the DDR is still in it's infancy stage, and very expensive to purchase (Kodak, 1999).

Going filmless is space saving and economically smart. Over 800 images can be stored on a single CD, eliminating the need for storage of bulky film jackets. Film processing chemicals, and silver coated film will be no longer be used, which will eliminate the need for special handling of the hazardous waste materials that are produced. This is also cost efficient and environmentally sound (Kodak, 2000).

Several vendors and equipment manufacturing companies

such as Fuji, Kodak, Agfa-Gavert, and General Electric,

have been involved for many years with developing,

refining and improving this technology. At first, this

technology was implemented into the practical application

in many of the large, high-dollar, university hospitals

and academic departments, and by research laboratories of

the major imaging manufacturers (Huang, 1999). As with any

technology though, improvement and reduction in cost have

allowed this technology to reach to the smaller imaging

centers as well.

Radiation Dose and Computed Radiography

According to Lawrence N. Rothenberg, PhD., an

associate attending physicists at Memorial Sloan-Kettering

Cancer Center in New York, computed radiography generally

requires a higher exposure and dose than film-screen

general radiography systems. "In my experience, the two

computed radiography systems, the average speed appears to

be somewhere in the range of 200 to 250, which is somewhat

less than the typical 400-speed film-screen system in

common use, a fact that does not seem to be highly

publicized by the manufactures of computed radiography

systems"(Sanchez, 2001, p.14).This leads to exposures that

are 1.5 to 2 times higher than those required for a

similar patient view produced on a radiographic film. On the other hand, CR systems used for portable radiographic exam require much less repeats than conventional film-screen images, due in part because after the exposure, the image can be adjusted to provide the best image without requiring an additional exposure to the patient. A great advantage of digital images is that they can be easily manipulated to provide the best radiographic detail.

The Educational Environment

The new millennium for radiologic technologist and the educators means looking not only at the growing need for computer literacy, but also the need to evaluate the level and relevancy of educational and clinical preparation needed to keep pace with the rapid changes and technological advances in the Radiological Sciences.

A distinguishing characteristic of radiologic sciences education is that much of the educational process occurs in the health care setting and is heavily influenced by that environment. It is more in the clinical environment than in the regular classroom that students acquire the concept of their professional role. How to improve student learning has been the topic of much research. Most educators agree that students should be

provided with and "education" instead of "vocational training." As a crucial part of the radiography program, the clinical environment must teach students how to develop and refine practical skills and clinical reasoning, but it is also important to teach students how to develop a "critical understanding" of what they are doing (ASRT, 1996). Radiologic science educators must meet the challenge of changing the educational paradigm. They hold the key to the development of the future work force (Sparks, 2000).

To meet this challenge of the changing educational paradigm, and assist with the educational process for educators and students, the idea to create a teaching model for computed radiography was conceived. It was hoped that this project will facilitate the teaching-learning process by integrating and applying the fundamental theories of computed radiography with the practical application in the clinical settings. In a broader scope, it was recognized that all of the radiologic curriculum should undergo similar evaluation to keep current and relevant to the constantly changing technology.

The educational needs of radiologic technologists dictates that those responsible for education in the field must look at a more comprehensive, contextual approach to

teaching radiologic technology principles, and specific to this project, electronic imaging fundamentals.

Contextual Learning

Contextual learning is a concept that helps teachers relate subject matter content to real world situations and motivates students to make connections between knowledge and its applications to their lives and workplace (U.S. Department of Education and the National School-to-Work Office, 2001). The application of contextual learning to American classrooms was first proposed by John Dewey, who advocated a curriculum and teaching methodology tied to the students' experiences and interests, and of school programs into academic and occupational tracks (Blanchard, 2000). All instructional experiences must be made relevant to all students with a context of careers and future work. The primary focus for educators should be on expanding the quantity and quality of ways in which a learner is exposed to content and context (Brodhead, 1992).

Secretary's Commission on Achieving Necessary
  Skills

The Secretary's Commission on Achieving Necessary Skills (SCANS) was asked to define the know-how needed in the workplace and to consider how this know-how is best assessed. In June 1991, this Commission produced a

32

document defining the workplace competencies and foundation skills required for effective job performance for today and tomorrow. SCANS message to teachers was to look beyond their discipline and their classroom to the other courses that students take. Help students connect what they learn in class to the world outside. When the SCANS Commission completed its work in 1993, the SCANS Center set out to implement its recommendations. This included, among others; integrating the SCANS skills explicitly in instruction at all levels, that all employers, incorporate the SCANS know-how into all their human resource development efforts and every employer in America should create its own strategic vision around the principles of the high-performance workplace. In education, teachers should blend the SCANS skills into their existing curricula, and to revamp their curricula in light of contextual-learning practices. SCANS principles are based on efforts to develop competency-based assessment methods that are practical and meet established criteria of reliability, fairness, and validity. Educators are beginning to find that well-developed performance-assessment is just as valuable for teaching and learning as for measuring student progress (U.S. Department Of Labor, 1992).

Competency-Based Education

Educators should focus on providing practice-orientated continuing professional education to meet the challenge of linking educational activities to professional practice while trying to avoid unrealistic expectations. If the material presented cannot be integrated into professional practice then the participants will become frustrated and will not learn (Sparks, 2000).

One way to integrate and validate this practice-oriented education is through using a model of competency-based education. In adult vocational, career and technical education, the trend toward competency-based education has been applauded. Competency-based education allows local licensing bodies to assess the skills and abilities of graduates coming from various areas of the country, with the degree of certainty that the education received is consistent and equitable (Sinclair-Bell and Mitchell, 2001).

The American Registry of Radiologic Technologists has recognized the validity of a competency-based education. Adopted in June 1998, the ARRT established core clinical competencies requirements that all individuals must demonstrate to establish eligibility for ARRT registration

by the year 2002. These requirements are in addition to graduation from an accredited educational program. The ARRT encourages individuals to obtain education and experience beyond the core requirements. The core clinical competencies are periodically updated to reflect changes in the requirements of professional practice. Students must demonstrate competency in all 39 of the mandatory radiological procedures and at least 10 of the 23 elective radiologic procedures. The ARRT recommends that educational programs include a mechanism of continuing and terminal competency evaluation to assure students maintain proficiency during the course of the program (ARRT, 2001).

Included on the list of elective competencies are categories for digital radiography and digital fluoroscopy. Students who are attending the El Camino College Radiologic Technology Program have an advantage over students who have not yet had exposure to digital radiography. The ECC students may perform a competency evaluation in digital radiography in the laboratory classroom on simulated phantoms.

The Vision - A Need for Change

Jean Piaget once wrote, "The principle goal of education is to create people who are capable of doing new things, not simply repeating what other generations have

done. The second goal of education is to form minds which can be critical, can verify and not accept everything they are offered" (Rogers, 2000, p.487).

The evolving nature of the health care system requires health professionals with skills and values different than those necessary in the past. This creates new roles and opportunities for some health professionals and limitations for others. Some interpret these developments as unreasonable encroachments on their freedom as professionals, while others find that these alterations permit some freedom and provide new opportunities. In the past century, radiologic science professionals have made significant contributions to health care. Now RT's must further refine who they are and what they will contribute in the context of rapidly changing health care needs (Sparks, 2000).

There is general agreement among educators and professional leaders that graduates of programs in the radiologic sciences should be both competent and involved professionals. They should be committed to improving their skills and defining their values through lifelong learning. The radiography student and technologist should also be evaluated through authentic assessment measurements. "Vocational educators have long favored

practical demonstrations of knowledge and competence"
(Little, 1992, p.28), the current emphasis on authentic
assessment (AA) meshes well with vocational-technical
education. Curriculum integration has become a hallmark of
educational reform, and vocational-technical educators
want to demonstrate that their curricula meet high
standards. AA meets these needs because it connects the
way schoolwork is assessed with the way knowledge and
competence are judged in the workplace. It focuses on
tasks that are meaningful to learners and linked to school
and workplace demands (Little 1992).

Authentic assessment is a framework that identifies
the domains of competencies critical for postsecondary
students, it describes the best practices of integrating
career preparation into the community college. Included in
these teaching approaches are authentic assessment and
work-based learning (Badway, 1997).

In the radiologic sciences, certain conceptual
understandings and technical performance standards dictate
unique goals or "professional competencies" that are of
primary concern to educators and the profession (Sinclair-
Bell and Mitchell, 1999).

These competencies include:

- Conceptual competence: an understanding of the theoretical foundations of the profession.

- Technical competence: the ability to perform skills required of the profession.

- Integrative competence: the ability to meld theory and skill in the practice setting.

Given the dynamics of change – educators should acknowledge 3 basic premises that underwrite the need for lifelong learning:

- Continual change in the role and function of the radiologic science professional must be expected and planned for.

- Formal educational processes cannot impart all necessary knowledge, skills and values for present or future professional competency.

- Teaching must be relevant and responsive to the needs of both the patient and the student (Sparks, 2000).

Educational research has shown that the distinction between knowing subject matter and knowing how to apply subject matter is a subtle one. The major difference may be that knowledge of subject matter requires only the lower-level cognitive skills of recall and recognition,

whereas the ability to apply subject matter requires the higher-level, complex skills of analysis and synthesis (Adler, 1997).

This is demonstrated daily in the clinical setting where the expected competencies are multidimensional (cognitive, psychomotor and affective). The application of knowledge in this area is clearly integrative (Van Valkenburg, Veale, Cladwell, Lapingnanao and Harifield, 2000).

At this time, it appears wise to begin planning educational patterns, curriculum, and work arrangements that contribute to improved health care. This effort should be designed to encourage the best possible use and education of the radiologic science professional. It also should be designed to achieve a greater degree of motivation and commitment on the part of students, faculty, and practitioners (Van Valkenburg, et al., 2000). This can only help to improve the much sought-after professional status and to fulfill the obligation and commitment to improve patient care. The quality of care and the skill application of the student or technologist are directly governed by the level of knowledge and skills that the professional maintains. The competence with which this care is provided depends on the skills of the

radiographer. Generally, the more broadly prepared the radiographer, the more likely that radiographer will be able to find employment. The growing demand for knowledgeable and qualified RT's only continues to increase. Job restructuring is a fact of life in today's continually changing health care industry. New health care roles demand a higher level of skill than ever before (Rosenfeld, Ottoman, and Leung, 1999). New technology and equipment require highly skilled and specialized technologists for operation (Tilson, Stickland, DeMarco and Gibson, 2001). To address the changes, the curriculum must also undergo review and revision to those changes (Weinstein, 1996).

Developing Curriculum

As stated in Curriculum Development in Vocational and Technical Education, curriculum is "The planned interaction between teachers and students that (hopefully) results in desired learning" (Finch & Crunkilton 1999, p. 44). Once basic skills have been identified all curriculum must be based on that framework (Finch & Crunkilton 1999). In order to develop curriculum, it is vital to include professionals in the given area. These professionals make

recommendations that may be used by instructors in the classroom.

Anticipating the increasing breadth of knowledge required by health care workers, the JRCERT Standards along with the ARRT have been broadly designed and reflect higher order thinking and performance skills. To train future health care workers to meet these standards, educators in all settings must rethink the ways in which they design curricula and courses (ASRT, 2000). While curriculum development and design is of primary interest to the education community, instruction is also integral to the work of clinical environment where the students spend the majority of their time and practice.

A number of curriculum development models exist for health care occupations. Most represent curriculum as the confluence of three major factors: the functions, or technical aspects of care; the health care worker's role, or the interpersonal aspect of care; and the context, or setting in which care is delivered. The curriculum designer must be sure to incorporate these elements into courses, either implicitly or explicitly.

One of the initial steps in the curriculum development process should be to establish goals and determine what should be accomplished with a new or

revamped curriculum. In 1994, the National Commission of Secondary Vocation Education published the following recommendations for vocational-technical programs:

- update curriculum to align more closely with changing industry needs

- revamp curriculum to highlight problem solving and thinking skills

- incorporate work-site learning components

If curriculum is to remain relevant to the changing technology and innovations, steps must be taken to keep it from becoming outdated. The extent to which a curriculum assists student to enter and succeed in the working world is what measures the success of a program (Finch & Crunkilton, 1999).

The list of scientific and technical developments that have impacted radiologic science education in the past decade is tremendous. The phenomenal growth of new knowledge is especially difficult because of the complexity of much of the new information. In addition, new approaches to this new knowledge demand new methods (Sparks, 2000). Therefore, educational objectives and curriculum should be derived not just from scientific and technical developments, but also from professional needs and from the demands of clinical environment.

Constant reappraisal is necessary if education is to be dynamic. Changes in the educational paradigm should result in more efficient and effective learning. The requisite knowledge, skills and attitude should be acquired in a meaningful way, producing graduates able to function as capable, contemporary professionals(Sparks, 2000).

It is up to educators to establish performance outcomes in academic and vocational-technical competencies. The ultimate goal when developing any vocational-technical curriculum is to prepare a student for a position in the workplace (Economic and Workforce Development, 2001).

There are many radiologic technology programs throughout the state providing some kind of training (didactic and clinical) for the radiologic technology student, but without specific guidelines, each program content and delivery varies with the instructor's expertise. Providing a sound, uniform, competency-based curriculum guideline with supporting documentation will help ensure the high quality patient care that our communities expect.

Educators have a responsibility to keep current of the new technological advances in the radiologic sciences.

The technological changes have a profound impact on vocational and technical education curricula. An advisory committee should be consulted to review course outlines and curriculums (Finch & Crunkilton, 1999). Curriculum evaluation helps a program to stay current with technology.

It would be impossible to change an entire curriculum all at once, but small changes over time can keep a curriculum fresh and students interested. Curriculum review should always have a positive impact on the curriculum, the program, or materials. Evaluation has the potential to assist vocational-technical educators in making meaningful improvements. It is important to evaluate the relevance of the program curriculum; does it reflects current clinical practice, new trends, and the needs of the student population? A well-designed curriculum should accomplish all of these goals(Dowd and Battles, 1996). Only those changes that benefit the students most should be made (Finch & Crunkilton, 1999).

The American Society of Radiologic Technologists (ASRT) sponsored the profession's first national Educational Consensus Conference in March 1995, to address the concerns and issues in preparing radiologic technologist for the 21st century. The findings from the

conference suggested that the profession's current

education models and curricula require a major overhaul to

prepare radiologic technologist for the next century

(ASRT. 2000).

In such a highly technical and constantly changing

field as the radiation sciences, this is a monumental

task, and curricular expansion is an ongoing process. One

way to help undertake this task is through collaboration

with other educators and professionals in the field

(Sparks and Greathouse, 2001). It is hoped that this

project will be a start to the process of collaboration

with other educators.

Work-Force Development and Job
Satisfaction

Fewer people entering the high-technology allied

health professions combined with a growing demand for

these professions, has led to a shortage in many of these

occupations. The projected supply of technologists in

radiology, for example, is not keeping up with the

projected demand. The Summit on Manpower, a coalition of

17 high technology health professional associations,

project that 6,000 radiologic technologists working in

diagnostic radiology areas will be needed per year in the

near future, where only 4,000 - 5,000 of the approximately

45

8,000 graduates from training programs annually will

continue to work in this area. The other graduates

continue into advanced modalities, or other areas outside

of radiology (Eubanks, 1990).

National data on college graduates in allied health

and other fields show that one of the most important

predictors of job satisfaction is a feeling that one's

skills are fully utilized on the job (Mehan, 2000).

Educators also recognize that the radiographers' ability

to build onto their entry-level skills in response to

changing health care trends would free them from the

feelings of entrapment associated with dead-end jobs and

provide them with an increased level of job satisfaction

and professionalism. Lifelong learning, as well as,

staying current with new modalities, can help with this

increased sense of responsibility and professionalism.

School to Work Relationships

Community colleges play a vital role in state and

local workforce development (Badway and Grubb, 1997). As

health care delivery becomes increasingly technological,

it is critical that employees and businesses have access

to training and retraining services. Community colleges

can provide these services, and lead the nation forward to

greater economic productivity. Cooperative education programs combine classroom learning and practical, paid, on-the-job experience in a particular field to the benefit of both students and employers (Brodhead, 1992). Students earn both salaries and credit for the learning that occurs on the job, while employers develop a skilled, literate workforce at a far lower cost than if they provided their own training. These programs often attract older, returning students in need of retraining (Hirschberg, 1991).

This is a common thread to many of the student population at El Camino College. One of the visions of the El Camino College Radiologic Technology Program was to develop a partnership with the Eastman Kodak Company, the manufacturer of the computed radiography equipment on the campus (D. Visintainer, personal communication, April 20, 2001). It is recognized that any educational endeavor should relate in some way to the community. School-to-workplace-community partnerships should exist. The community is obligated to indicate what their needs are and to assist the school in meeting these needs. It should be recognized that strong school-workplace community partnerships may often be equated with curriculum quality and success (Finch & Crunkilton, 1999). Educating working

47

professionals in the field was one of the rationales
behind undertaking the enormous task of purchasing a
Computed Radiography system for a college campus.
Equipment upgrades are periodically needed, by involving
Kodak with an educational partnership, assures system
upgrades will be in place to stay current with the
changing technology.

Funding Issues

Academic leaders must be visionary, and they must
prepare their establishments to become the organizations
of the future. Donald Visinatiner, Program Director for El
Camino College Radiologic Technology Program, is one such
visionary leader. He saw where the future of technology
was leading, and took measures to bring it to the college
campus. Developing a vision of the future is especially
critical for the allied health disciple of radiography.
The ultimate goal of any allied health educational program
is to develop practitioners who are competent in the
technology of their discipline, can meet the needs of
patients and can adapt to future trends.

The Carl D. Perkins Vocational and Technical
Education Act (VTEA) of 1991 was instrumental in helping
to provide funds needed to purchase this equipment for an

on-campus laboratory. The final cost was over $350,000.00.

Mr. Visintainer wrote successfully funded grants from the

State of California, Performance for Excellence (P4E), and

the Carl D. Perkins Vocational Assistance Act.

Signed into law on October 31, 1998, the Carl D.

Perkins Vocational and Technical Education Act (VTEA) of

1998 (Perkins III) sets out a new vision of vocational and

technical education for the 21st century. The central

goals of this new vision are improving student achievement

and preparing students for postsecondary education,

further learning, and careers.

Perkins III promotes reform, innovation, and

continuous improvement in vocational and technical

education to ensure that students acquire the skills and

knowledge they need to meet challenging State academic

standards and industry-recognized skill standards, and to

prepare for postsecondary education, further learning, and

a wide range of opportunities in high-skill, high-wage

careers (US DOE, 2002).

Summary

The literature important to the project was presented

in Chapter Two. A history of the discovery of x-rays, the

technological developments in the field of radiologic

technology, and the role and duties of a radiologic technologist were discussed. The educational requirements, the educational environment, the need for curriculum review, development, and alignment were also discussed. Integration of the educational process from the classroom to on the job activities were emphasized. The importance of competency-based, relevant, contextual, and life-long education were stressed. The role of the community college in work-force development and funding issues were also discussed.

The focus of the literature review emphasized the need to develop a curriculum guide on computed radiography to help educators and students stay informed and current in these new technologies used in the professional practice.

Providing a competent radiographer requires a balance of disciplines in the didactic setting of a college, synchronized with the application of knowledge in the clinical settings in the health care environment. Clinical practitioners and supervisors rated electronic imaging and computed radiography as an important entry-level skill and knowledge for competent performance by a newly certified radiographer. The research concludes that there is a sound

basis for considering the improved coverage of these knowledge areas (Rosenfeld, et. al., 1999).

To help identify the tasks, skills, or competencies that should be included in the project, research and investigation of existing electronic databases, literature, and professional journals were reviewed. In addition, a small advisory committee was formed. A curriculum guide to teach computed radiography was developed by consulting with experts in the field, other educators, radiologic technologist currently using computed radiography equipment, department managers, students, and the ASRT.

CHAPTER THREE

METHODOLOGY

Introduction

Chapter Three documents the steps used in developing the project. Specifically, a concise and systematic approach to curriculum development for teaching the fundamentals of computed radiography.

Population Served

The project was developed to serve the educators of the radiologic technology students and registered radiologic technologist. The radiologic technology student may be enrolled in a Radiologic Technology program at a community college, university, or a hospital based program. The registered radiologic technologist may be someone who is working in the field and needs to update their skills and learn the fundamentals and basics of the computed radiography equipment.

The project was designed as a handbook for educators and managers, to enable them to teach the fundamentals of computed radiography in a consolidated and concise but simplified format using integration of the theory with actual clinical practice.

Certification Requirements

A radiology technology program must be at least 24 months in length, and meet the standards for competency as set forth by the ARRT. The program must include a specific amount of clinical and didactic education. As of January 2002, the ARRT published standards of minimum competencies that must be met before the student is eligible to sit for the state and national registry exam. In addition, the student must complete a minimum of 2000 hours of clinical education and instruction during the course of the program as required by the State of California, Radiologic Health Branch (RHB).

The competencies identified as essential to mastery and understanding of computed radiography concepts were extracted from the ARRT curriculum draft and are included in the curriculum outline.

Curriculum Development

The next section of the project provides an overview of the curriculum development process. Specifically, the curriculum structure and content validation process are reviewed.

Curriculum Design

This core curriculum guideline was developed in accordance with the standards set forth by the ARRT

curriculum draft published in late 2001. Educators and specialist in the field, as well as radiologic technologist currently working with computed radiography equipment and PACS administrators provided input and expert consultations. Mr. Donald Visintainer, R.T., Program Director at El Camino College, Mr. Rolly Reyes, R.T., Educator at El Camino College, and Ms. Kathryn Kneeburg, R.T., Eastman Kodak Applications Specialist were instrumental in providing the necessary information to organize this curriculum. The content was assimilated from a variety of sources as mentioned in the literature review. This included textbooks, journal articles and many websites on the world wide web.

The curriculum is designed to be used as a stand alone course, or integrated a part of the radiographic physics and principles courses. It is recommended that the content be presented after the student has received basic theory in fundamentals of x-ray production and interaction, technique considerations and the relationship of kiloVoltage pulse (kVp) and milliaperage seconds (mAs) to radiographic density and contrast. Theory discussing the components of film/screen combinations, image evaluation and standard projection radiography is also recommended.

A basic understanding of computer applications, such as use of a mouse, keyboard, and word processing is also necessary prior to lectures in computed radiography. Most colleges require a basic computer applications course be taken by all students as part of the general education requirements, therefore, the basic computer skills class will be considered a prerequisite course for this curriculum.

The curriculum is divided into one to two hour lesson plans. Depending on the student's command of computer applications, some of the lesson plans may take more or less time to teach. Each lesson plan will build on the previous. The project is designed to present the information in a concise and logical order, to help the student and educators better understand and master the fundamentals of computed radiography. Theses fundamentals are included in the project.

Prerequisites

Admission in or completion of a radiographic technology program. Completion of at least one semester of radiation physics, production and application principles and a basic computers operation course.

Curriculum Development

Curriculum Resources and Content Validation

According to Finch and Crunkilton, (1999), the focus in vocational and technical curriculum deals directly with helping the student to develop a broad range of skills and knowledge which ultimately contributes to the graduate's employability. The focus of the vocational and technical education learning environment makes provisions for the student integration of academic studies to applied vocational application. Although it is important for students and practicing radiographers to be knowledgeable about many aspects of the occupation, the true assessment of success in school or the work environment must be apparent with the "hands-on" or applied performance (Finch and Crunkilton, 1999).

As stated earlier, the ARRT held the first National Educational Consensus Conference in March 1995, to address the concerns and issues in preparing radiologic technologist for the 21st century. The findings from the conference suggested that the profession's current education models and curricula require a major overhaul to prepare radiologic technologist for the next century (ASRT. 2000).

56

The 21st century is here, and computed radiography is quickly overtaking many of the medical imaging departments. Providing a handbook to teach the new computed radiography is a step towards preparing the current and future radiologic technologists.

The content of the handbook was validated by a small advisory committee consisting of members of the medical community, a Kodak field engineer, an applications specialist, technologist currently using the equipment, and educators in the radiologic sciences.

Curriculum Design

Curriculum design is based on research and experience, and is rooted in the belief that the educator needs to know what is actually being used in the clinical environment, and apply this to what is taught in the class. Curriculum design is a process to solve the time management problems from which all educators suffer, while helping to create more effective courses and programs (Weinstein, 1986).

The curriculum design for this project is presented in the Appendix.

Summary

The steps used to develop this project were outlined. The target populations for this course were the educators of the radiologic technology students and registered radiologic technologists. The curriculum development process including curriculum structure and content was presented. Upon completion, this curriculum guideline project will be offered to educators and to the American Society of Radiologic Technologist for adoption as the national standard for curriculum guidelines for electronic imaging and computed radiography.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Included in Chapter Four was a presentation of the

conclusions gleamed as a result of completing the project.

Further, the recommendations extracted from the project

are presented. Lastly, the Chapter concludes with a

summary.

The conclusion extracted from this project follow:

1. In researching for this project, the conclusion

     was made that since limited curriculum

     guidelines exist, the development of a handbook

     to teach computed radiography was necessary.

2. Current radiologic technology programs and

     medical imaging departments can be limited by

     the lack of training in this area. Educators,

     radiologic technologists and students will all

     benefit from established guidelines and handbook

     of lesson plans.

Recommendations

The recommendations resulting from this project

follow:

1. Further development of the curriculum should include revisions that reflect the technological advances in the field.

2. It was strongly recommended that this curriculum be taught by registered radiologic technology educators or department in-service managers to ensure quality instruction and maintain relevant correlation with the theory and practical application of the concepts.

3. Further development of the curriculum should include expansion of the outlines and lesson plans provided through collaboration with other educators. Development of comprehension and evaluation materials are also needed.

4. Further development of the project for use as a distance learning course could increase the potential population served. On line education would enable a radiologic technologist the ability to learn quickly and without leaving their job or home. With good design, the project could be modified to upgrade the skills of the working professionals, and offer continuing education units. The Internet offers many additional educational opportunities.

Summary

Chapter Four reviewed the conclusions extracted from the project. Lastly, the recommendations derived from the project were presented.

APPENDIX

CURRICULUM GUIDE

Curriculum Guide
for
Computed Radiography
at El Camino College

Table of Contents

65

Section A

Introduction

Amazing advancements have been accomplished in the radiologic sciences during the past decade. Since the discovery of x-ray in 1896, until the recent acquisitions of computers, radiographic imaging was basically accomplished the same way. An x-ray beam of photons was passed through an object (human) onto an imaging plate that contained radiographic film. The film was then processed in a chemical solution until an image was produced.

New and revolutionary technology has rapidly advanced into the radiologic sciences since the incorporation of computers in the early 1970's. The diversity and improvements that computers have generated, particularly in the past few years has been the most significant achievement since the original discovery.

The computer has revolutionized diagnostic imaging, making possible such advances as computed tomography, magnetic resonance imaging, sonography and computed radiography (CR).

Computed Radiography (CR), also known as digital or electronic imaging, is a general term used to describe a system that electronically records a radiographic image. Computed radiography systems use unique imaging receptors to capture an analog image and sophisticated readers to process the image and convert the information to a digital format. In conventional imaging, visible details of human structure are recorded on film, and once they are obtained, the image cannot be altered. Since CR utilizes digital technology, these images may be electronically manipulated to adjust for contrast and brightness. The computer-generated images obtained with CR may be displayed electronically or on film.

This new explosion in technologies have significantly impacted the radiologic sciences; the radiologic technologist, the educators, radiologists, administrators, and students have all been affected.

As the technology evolves, the number of qualified radiologic technology professionals who are proficient in the theory, application, and operation of these powerful new technologies are limited.

This handbook was developed for educators and administrators to teach computed radiography to the radiologic technology student or practicing radiographer suddenly surrounded by this new technology. These lessons can be used as a stand-alone course, or integrated into existing radiologic technology courses.

The information was complied from many resources, and condensed into a simplified, but comprehensive and concise format to help educators assimilate the information to their students. This project is designed to incorporate the theory components of computed radiography into an integrated, contextual, "hands-on" skills practices in the computerized lab or clinical settings.

Section B

Course Curriculum

Outline Electronic Imaging

Electronic Imaging

Course Description

1. Content is designed to establish a knowledge base in computed radiographic and digital fluoroscopic equipment.
2. Electronic imaging with related accessories will be emphasized. Class demonstrations and labs are used to demonstrate application of theory.

Course Objectives

At the completion of the content outline, the student radiographer will:
1. Discuss electronic imaging equipment used in radiography and fluoroscopy.
2. Discuss flat panel detectors used in digital electronic x-ray equipment.
3. List image archiving options.
4. Discuss photostimulable phosphor plates as image receptors.
5. Explain latent image formation on the photostimulable phosphor (PSP).
6. Discuss how an image is retrieved from a photostimulable phosphor (PSP).
7. Differentiate between traditional intensifying screens and photostimulable phosphors.
8. Differentiate between the purpose of the automatic and dry processors
9. Describe the operation and utilization of dry processing.
10. Discuss digital image processing and post-processing.
11. Given images containing artifacts, determine the type of artifacts, and analyze the artifacts to determine the cause.

Content

I. Computed Radiographic Equipment/ Electronic Imaging
   A. Purpose
   B. Principles
   C. Equipment
      1. Flat panel detectors
         a. Description
         b. Function
         c. Types
            1) Amorphous silicon
            2) Amorphous selenium
            3) Charge coupled device (CCD)
      1. Thin film transistor (TFT)
      2. Photostimulable phosphors
      3. Processing
         a. Automatic
         b. Dry
   D. Digital systems (Windowing)
      1. Signal to noise ratio
      2. Motion blur
         a. Image noise
         b. Quantum mottle
         c. Signal to noise ratio

II. Exposure Latitude
   A. Definition
   B. Factors
      1. kVp
      2. Intensifying screens
      3. Film
      4. Photostimulable phosphors
      5. Computed system
      6. Image receptor

III. Beam-Limiting Devices
   A. Definition
   B. Purposes
   C. Effect on CR radiography
      1. Light field
      2. CR
      3. Alignment

IV. Grids
    A.   Purpose
    B.   Components
    C.   Construction
    D.   Efficiency
        1.   Ratio
        2.   Frequency (lead content)
    E.   Selection
    F.   F. kVp
    G.   Patient considerations

V. Technique Formulation
    A.   Purpose
        1.   Standardization of exposure
        2.   Image consistency
    B.   Considerations
        1.   Choice of technique system
        2.   Patient measurement
        3.   Image processing
    C.   Types
        1.   Optimum kVp/variable mAs
        2.   Variable kVp/fixed mAs
        3.   Automated exposure
        4.   Digital
    D.   Applications

VI. Exposure Calculations
    A.   mAs
    B.   kVp
    C.   Digital exposure indicator
        1.   Average gradient
        2.   Focal Spot Blur

VII.   Image Receptor Handling and Storage
     A.   Processing considerations
         1.   Light
         2.   Radiation
         3.   Handling
     B.   Storage considerations
         1.   Temperature
         2.   Humidity
         3.   Light
         4.   Radiation
         5.   Gases/fumes
         6.   Handling
         7.   Pressure
         8.   Expiration date

VIII.   Characteristics of Image Receptors
     A.   Composition
         1.   Components
         2.   Structure
         3.   Function
     B.   Types
         1.   Film
         2.   Photostimulable phosphors
             a.   Construction
             b.   Applications
     C.   Definition, influence and application of image receptors properties
         1.   Contrast
         2.   Speed/sensitivity
     D.   Digital systems
         1.   Definition/purpose
         2.   Sensitometric equipment
         3.   Graphing
     E.   Interpretation
         1.   Curve construction and graphing
         2.   Evaluation
         3.   Histograms

IX.   Processing of the Images
        A.   Digital Units
                1.   Purpose
                2.   Structure
                        a.   Components
                        b.   Function
        B.   Systems/functions
                1.   Dry processing
        C.   Digital image processors
                1.   Equipment
                2.   Latent image conversion

X.   Digital Processing
        A.   Algorithms
        B.   Histograms
        C.   Resolution
        D.   Post-processing
                1.   Edge enhancement
                2.   Smoothing
                3.   Magnification
        E.   Exposure indicator (patient dose)

XI.   Artifacts
        A.   Definition
        B.   Types
        C.   Causes
        D.   Effects
        E.   Preventive/corrective maintenance

Section C

Course Curriculum

Computers in Radiology

Computers in Radiology

Course Description

1. Content establishes introductory knowledge in computing and information processing.
2. Computer applications in the radiologic sciences related to image capture, display, storage and distribution are presented.

Course Objectives

1. Identify the various types of computers.
2. Briefly define analog to digital conversion and digital signal processor.
3. Identify various terms related to computer fundamentals and components.
4. Describe major functions of Central Processing Unit (CPU).
5. Differentiate the various input and output devices.
6. Describe the types of memory.
7. Describe computer care and preventive maintenance.
8. Explain computer operation.
9. Describe analog to digital conversion.
10. Distinguish between analog computers and digital computers.
11. Explain the binary function.
12. Discuss application of various types of software.
13. Describe the following computing applications as they relate to radiology:
   radiologic information systems (RIS),
   hospital information systems (HIS),
   picture archiving communication systems (PACS).
14. Define DICOM.

Content

I. Fundamentals
    A. Types of computers
        1. General purpose and mainframe
        2. Minicomputer
        3. Microcomputer
    B. Key concepts
        1. Analog to digital conversion (A-D conversion)
        2. Digital signal processor (DSP)
    C. Terminology

II. Components
    A. Central processing unit (CPU)
        1. Arithmetic logic unit (ALU)
        2. Control unit (CU)
        3. Memory
    B. Input and output devices (I/O) (peripherals)
        1. Input
            a. Keyboards
            b. Video terminals
            c. Mouse
            d. Light pen/laser
            e. Voice entry
            f. Digital cameras
            g. Image scanner
        2. Output
            a. Printers
            b. Video monitors
            c. Graphic displays
            d. Voice output
        3. Storage/memory
            a. Primary memory
                1) Random access memory (RAM)
                2) Read only memory (ROM)
            b. Secondary storage

III. Operations
  A. Terminology
     1. Analog
     2. Digital
     3. Binary
  B. Programming
     1. Definition
     2. Purpose
     3. Language
     4. Software
        a. Word processing
        b. Data base
        c. Spread sheet
        d. Desktop publishing
        e. Graphics
        f. Integrated application programs
  C. Considerations
     1. Environmental conditions
     2. Computer catastrophes
     3. Ethical/legal concerns
     4. Preventive maintenance
     5. Confidentiality
     6. Security
        a. Passwords
        b. Limited access
        c. Firewalls

IV. Radiology Applications
  A. Digital radiology
  B. Patient information and systems scheduling
  C. Quality control and quality assurance
  D. Picture archiving communication systems (PACS)
  E. Hospital information systems (HIS)
  F. Radiology information systems (RIS)
  G. Digital imaging and communications in medicine (DICOM)

Section D

Lesson Plans

Lesson One
Introduction to Computed Radiography

Objectives

At the completion of this lesson, the student radiographer will be able to:

1. Define and differentiate the concept of electronic imaging from conventional imaging.
2. Describe the types of digital imaging performed in a radiography department.
3. Compare and contrast types of equipment used between digital imaging and conventional film/screen radiography.
4. Discuss the benefits that computed radiography provides to the radiographer, radiologist, referring physician, and the patient.
5. Specify a minimum of three advantages and one disadvantage of computed radiography.
6. Discuss the historical development of computed radiography and formulate a timeline describing the early implementation of CR systems to the current state of the art technology.
7. Compare the similarities and differences of electronic imaging equipment used in radiography and fluoroscopy.
8. Describe flat panel detectors and photostimulable phosphor plates as image receptors used in digital equipment.
9. Differentiate between digital and conventional radiographic latent and manifest image production.
10. Explain latent image formation on the photostimulable phosphor (PSP).
11. Discuss how an image is retrieved from a photostimulable phosphor (PSP).
12. Differentiate between traditional intensifying screens and photostimulable phosphors.
13. Differentiate between direct and indirect conversion image receptors.
14. Describe photostimulated luminescence phenomenon and explain why it is necessary to produce a CR image.
15. Given a diagram of an imaging plate, correctly identify the various layers of IP construction.
16. Describe each step involved in CR image processing.
17. Specify the most common image display formats utilized with CR systems.

Outline: Introduction to Computed Radiography

I.   Terminology
     A.   Computed Radiography (CR)
     B.   Digital Imaging (DR)
     C.   Electronic Imaging
     D.   Direct Digital Imaging (DDR)
     E.   Computer Assisted Radiology (CAR)
     F.   Conventional Projection Radiography

II. History
     A.   Dr. Paul Capp introduces "digital radiology" in 1970.
     B.   University of Wisconsin and University of Arizona begin studies in digital fluoroscopy in 1970's
     C.   1981 Fuji introduces photostimulable phosphor plate technology at ICR Brussels
     D.   First International Conference on PACS held in Newport Beach, CA in 1982
     E.   One of the earliest research projects in the United States related to PACS and the U.S. Army sponsored teleradiography project in 1983.
     F.   1983 first clinical use in Japan
     G.   By 1998 over 5000 systems in clinical use worldwide
          1.   Simple units with film digitizers and monitors
          2.   Complex total hospital imaging management system
               a.   Transition of other modalities to digital
               b.   CT, MRI, US, Nuclear Med

III. Description
     A.   Conventional Projection Radiography - 70% of exams
     B.   Digital Radiography – 30 % of exams
          1.   Computed Radiography (CR)
               a.   Photostimulable Phosphors
          2.   Direct to Digital Radiography (DDR)
               a.   solid state x-ray detectors
               b.   thermoluceint film transistors
               c.   instant viewing of images

IV. Comparisons to Film/Screen Radiography
    A. Similarities
        1. Basic radiographic equipment
        2. Projection radiography
        3. Exposure Factors
            a. KiloVoltage (kV)
            b. Milliamperage (mA)
            c. Time (S)
    B. Differences
        1. Image acquisition device (plate)
        2. Image processing
        3. Soft copy vs. hard copy
        4. Ability to change image appearance after acquisition (post-processing)
        5. Ability to transmit electronic image data to multiple sites simultaneously
    C. Advantages of digital radiography
    D. Disadvantages of digital radiography

V. Computers in Radiology
    A. Basic Computer Functions
        1. Mouse and Keyboard Functions
        2. Basic operating functions
    B. Electronic manipulation
        1. Image acquisition
        2. Adjust contrast and brightness
    C. Computer algorithms
        1. Histogram analysis
        2. Pixels and Matrix

VI. Benefits
    A. To the radiographer
        1. Less time
        2. Ability to manipulate image quality
    B. To the radiologist
        1. Less time to see images
        2. Ability to manipulate image quality
        3. Various Image Display Tools
        4. Comparison and correlation with images from other modalities
        5. Rapid image retrieval of images
        6. Information sharing with other physicians (radiologists)

C. To the referring physician (clinician)
   1. Ability to see patient images more quickly
   2. Image can be viewed from multiple sites external to Radiology/Medical Imaging Department
D. To the patient
   1. Potential for reduction in radiation exposure
   2. Exams more quickly performed
   3. Potential for improved outcomes due to more rapid and accurate image interpretation.

Lesson Two
Computers in Medical Imaging

Lesson Two

At the completion of this lesson, the student radiographer will be able to:
1. Name six areas in the Radiology/Medical Imaging Department where computers are used.
2. Define what a "Hospital Information System" is.
3. Compare the "Radiology Information System" with the Hospital Information System.
4. Describe what "teleradiology" is and how it is used today.
5. List at least three benefits of a teleradiology system.

Outline :Computers in Medical Imaging

I. Where computers are found
    A. Hospital Information Systems (HIS)
    B. Radiology Information Systems (RIS) – Radiology/Medical Imaging Department

II. Computers used in medical imaging
    A. Digital Image Acquisition
        1. Digital Radiography
        2. Digital Fluoroscopy
        3. Computed Tomography (CT)
        4. Diagnostic Ultrasound (US)
        5. Magnetic Resonance Imaging (MRI)
        6. Nuclear Medicine
    B. Computer Assisted Diagnosis (CAD)
        1. Developing technology
        2. Second opinion readings
    C. Voice Recognition
        1. Automated transcription of image interpretation (dictation)
        2. Patient's Medical Record
            a. Conventional Medical Record (hard copy)
            b. Electronic Medical Record (EMR)
    D. Teleradiology
        1. Image interpretation after hours
        2. Additional image interpretation

Lesson Three
Radiographic Exposure Considerations

Objectives

At the completion of this lesson, the student radiographer will be able to:

1. Compare the similarities the exposure factors (mA, kV, Time) share with respect to image quality in both conventional film/screen imaging and digital imaging.
2. State the major objective of radiographic exposure selection for images made with digital imaging.
3. Identify and explain the significance of the Exposure Indicators utilized by three Computed Radiography (CR) vendors.
4. List one pitfall of the computer's ability to correct an image in the event of incorrect radiographic exposure selection.
5. List and describe two radiographic views/projections where special attention must be paid with respect to a CR system.
6. Name the recommended grid ratio and grid density for a grid cap to be used for a CR exposure.

Outline: Radiographic Exposure Considerations

I.   Radiographic Exposure Factors
    A.   kiloVoltage (kV)
    B.   milliAmperage (mA)
    C.   Time (S)

II.   Similarities with conventional film/screen imaging
    A.   kiloVoltage
        1.   penetration of anatomic structure
        2.   controls image contrast
    B.   milliAmperage
        1.   quantity of radiation exposure
        2.   affects image density
        3.   affects image sharpness and detail
    C.   Time
        1.   length of radiation exposure
        2.   works with mA to create total mAs in exposure
        3.   affects image sharpness & blur

III.   Differences with conventional film/screen imaging
    A.   kV range for digital radiography typically higher
    B.   exposure objective to get photons to image receptor, allowing computer algorithm to adjust image contrast

IV.   Radiographic Exposure Indicators
    A.   Vendor specific
        1.   Eastman Kodak – Exposure Index
        2.   Fuji Medical – "S" Number
        3.   Agfa Medical – lgM
    B.   Indicates over- or under-exposure compared to recommended range
    C.   Computer correction of image
    D.   Pitfalls
        1.   Usage of improper radiographic exposures
        2.   Potential for radiation over-exposure of patient
        3.   Potential for radiographer "auto pilot" mentality

V. Special Radiographic Projections/Views
    A. Body Part algorithm override
    B. Different techniques depending on vendor
    C. Single vs. multiple exposures on single imaging plate
        1. Vendor specific
        2. Specific techniques
    D. Grid Caps
        1. Vendor recommendation for grid ratios
        2. Positioning of grid cap

Lesson Four
Digital Radiography: Image Acquisition

Objectives

At the completion of this lesson, the student radiographer will be able to:
1. Describe the basic differences between direct image capture (DR) and indirect image capture (CR).
2. State four radiographer utilized imaging techniques that are important in digital radiography.
3. Diagram a schematic of a conventional imaging system.
4. Diagram a schematic of an electronic imaging system.
5. List and describe the basic functions of the three types of image detectors used in Direct Radiography.
6. Differentiate between direct and indirect methods of flat-panel image acquisition technologies.
7. Give another name for photostimulable phosphor radiography.
8. Explain the image capture process in a photostimulable phosphor plate.

Outline: Digital Radiography: Image Acquisition

I. Types (2)
    A. Direct Capture
        1. Direct to Digital Radiography (DDR)
    B. Indirect Capture
        1. Computed Radiography (CR)
        2. Laser Scanning Input Devices

II. Radiographer requirements
    A. Proper patient positioning
    B. Correct use of imaging techniques
        1. beam restriction (collimation)
        2. letter marker placement
    C. Proper radiographic exposure (optimized for digital imaging system)
    D. Computer proficiency
    E. Knowledge of good image quality
        1. radiographer manipulates image before "sending" to radiologist

III. Image Data Acquisition
    A. Review Conventional Imaging Systems flow diagram
    B. Electronic Imaging Schematic
        1. digitization of analog image (ADC) analog to digital conversion
        2. digital to analog image (DAC) digital to analog conversion

IV. Image Acquisition – [Direct] Digital Radiography (DDR)
    A. Detector Types (3)
        1. Charge Coupled Device (CCD)
        2. Indirect image capture
        3. Direct image capture
    B. Charge Coupled Device
    C. Flat-Panel Technology
        1. Indirect Method
            a. Scintillator
            b. Light Photodiode (Silicon)
            c. Thin Film Transistor (TFT)
        2. Direct Method
            a. Micro-plated electrode
            b. Amorphous Selenium semiconductor
            c. Thin Film Transistor (TFT)

V. Image Acquisition – Computed Radiography (CR)
- A. Other terms related to CR
  1. Storage Phosphor Radiography
  2. Photostimulable Phosphor Radiography
  3. Radioluminography
  4. Digital Luminescence Radiography
- B. Photostimulable Phosphor Plate (PSP)
  1. Phosphor construction
  2. Sizes
- C. Image Cassette
  1. Function
  2. Sizes
  3. Comparison to conventional film/screen cassettes
- D. Image Acquisition Process (steps)
  1. Cassette identified with patient demographic data
     a. Integration with HIS/RIS interface
     b. Body part algorithm selected
  2. X-ray exposure of PSP plate
  3. PSP plate stores energy

Lesson Five
Image [Data] Processing

Objectives

At the completion of this lesson, the student radiographer will be able to:
1. Describe the steps involved in processing the acquired digital data to produce an image in Direct Radiography.
2. Describe the steps involved in converting the data stored in the photostimulable phosphor to digital electronic data in Computed Radiography.
3. Define a pixel, and describe its role in an image matrix.
4. Describe an image matrix, and give an example of a typical matrix size currently used in digital radiography.
5. Explain the significance of pixel bit depth.
6. State one advantage and one disadvantage of a large matrix size.
7. Define a computer algorithm.

Outline: Image [Data] Processing

I.   Image Processing Steps (DDR)
      B.   Electrical signal amplified
      C.   Analog signal converted to digital signal (ADC)
      D.   Image processor applies algorithms
          1.   Image histogram created
          2.   Compare to Look Up Tables (LUT) for body parts selected
          3.   Brightness and Contrast algorithm applied
      E.   Soft copy image displayed on monitor
      F.   Accept/Reject image
      G.   Image data sent to workstation and/or archive

II.   Image Processing Steps (CR)
      A.   Cassette placed in image processor (reader, ADC)
      B.   PSP plate raster scanned by high intensity laser
      C.   Energy trapped by PSP released as visible light
      D.   Photomultiplier Tube (PMT) converts visible light analog electrical signal
      E.   Electrical signal amplified
      F.   Analog signal converted to digital signal (ADC)
      G.   Image processor applies algorithms
          1.   Image histogram created
          2.   Compare to Look Up Tables (LUT) for body parts selected
          3.   Brightness and Contrast algorithm applied
      H.   Soft copy image displayed on monitor
      I.   Accept/Reject image
      J.   Image data sent to workstation and/or archive
      K.   PSP plate erasure by exposure to white light
      L.   PSP plate reloaded into cassette
      M.   Cassette ready for next exposure

III. Image Matrix
    A.   Raster Scanning
    B.   pixels
        1.   defined
        2.   digital imaging
    C.   Image Matrix Size
        1.   number of pixel rows
        2.   number of pixels per row
        3.   bit depth (for gray scale)
    D.   Standard Resolution Matrix Size
    E.   High Resolution Matrix Size
    F.   Advantages of large matrix size
    G.   Disadvantages of large matrix size

IV. Algorithms
    A.   Defined
    B.   Types
        1.   window (brightness/density)
        2.   leveling (contrast/gray scale)
        3.   data compression
    C.   Data Compression
        1.   Defined
        2.   Why data is compressed
        3.   Types of data compression
            a.   "Lossless" (<2:1)
            b.   "Lossy" (>2:1)
        4.   Advantages of high data compression
        5.   Disadvantages of high data compression
        6.   DICOM Standard

Lesson Six
Image Display/Review Workstations

Objectives

At the completion of this lesson, the student radiographer will be able to:
1. Differentiate between Image Review and Image Display.
2. State one advantage of an electronic image display system.
3. State one disadvantage of an electronic image display system.
4. List three common characteristics of image display monitors currently in use.
5. Define an image display/review workstation.

Outline: Image Display/Review Workstations

I.   Definitions
    A.   Display Workstation – local
    B.   Review Workstation – remote

II.   Advantages
    A.   Image sharing across network
    B.   Eliminate necessity for film illuminator

III.   Disadvantages
    A.   Must have computer and monitor
    B.   Multiple monitors may yield different image quality
    C.   Require constant calibration
    D.   Can be very expensive

IV.   Characteristics
    A.   Currently all analog
        1.   Requires Digital to Analog Converter (DAC)
    B.   High resolution, black & white monitors
        1.   Special monitors
        2.   Special video cards for microprocessor
    C.   Most common sizes
        1.   17”
        2.   21”
    D.   Common configurations
        1.   Single monitor
        2.   Dual monitors (2-bank)
        3.   Quad monitors (4-bank)
    E.   Image Display
        1.   Individual images on individual monitors
        2.   Single image on multiple monitors
        3.   Multiple images on multiple monitors

V. Functions
- A. Algorithms applied to image data pool
- B. Tools
  1. window
  2. level
  3. Magnification
  4. Image zoom
  5. Pan and roam
  6. Reverse polarity
  7. Alter image orientation
- C. Physician-specific preferences
  1. "Hanging Protocols"

VI. Types (4)
- A. Image QC Workstation
  1. Image QC at Processor
- B. Diagnostic Workstation
  1. Radiologist's interpretation (reading) of images
- C. Clinical Workstation
  1. Remote to Radiology/Medical Imaging Department
     - a. patient floors (e.g. ICU, CCU, OR, ER)
     - b. selected locations throughout facility
     - c. connected by network
  2. Allows physician/clinician access to patient images without need for coming to Radiology/Medical Imaging Department
- D. Web Browser
  1. PC-based
  2. Images accessed via Internet

Lesson Seven:
Image Archiving

Objectives

At the completion of this lesson, the student radiographer will be able to:

1. Explain the concept of image data archiving.
2. Give three reasons for image data archiving.
3. Compare and contrast image archiving on film as opposed to an electronic medium.
4. List the basic classifications of archive systems, and give an example of each.
5. Name three important requirements of an electronic data archiving system.
6. Differentiate between "Short-Term" and "Long-Term" archive configurations.
7. Define "RAID" and state the major advantage of a RAID system for archiving.

<u>Outline: Image Archiving</u>

I.   Archiving defined

II.   Reasons for archiving
    A.   Patient history/progress
    B.   Clinical comparison
    C.   Medico-Legal

III.   Functions
    A.   Image data storage
    B.   Retrieval of stored image data

IV.   Comparisons with film archiving
    A.   Advantages of film
    B.   Disadvantages of film

V.   Basic Classifications
    A.   Media-based
        1.   analog format
            a.   SVHS tape
            b.   analog optical disk (AOD)
        2.   digital format
            a.   laser optical disk (LOD)
                i.   Compact Disk – Recordable (CD-R)
                ii.   Compact Disk – Rewritable (CD-RW)
                iii.   Digital Video Disk – Recordable (DVD-R)
                iv.   Digital Video Disk – Rewritable (DVD-RW)
            b.   Magneto Optical Disk (MOD)
            c.   Digital Linear Tape (DLT)
            d.   Redundant Array of Independent Disks (RAID)
    B.   Network-based
        1.   Application Service Provider (ASP)

VI.   Requirements
    A.   Ability to store vast amounts of electronic data
        1.   Average radiographic image approximately 10 MB of uncompressed data
    B.   Ability to retrieve data quickly and accurately
    C.   Image data integrity is uncompromised

VII. Archive Configurations
- A. Short-Term
  1. Timeframe is facility dependent
  2. Usually accomplished with RAID
- B. Long-Term
  1. How long and how much image data is kept is facility dependent
  2. Increased archive data volume = increased cost, slower retrieval times
  3. Multiple RAID, mass media storage device ("jukebox" for DLT, DVD)
  4. Application Service Provider (ASP)
     - a. operation
     - b. advantages
     - c. disadvantages

Lesson Eight:
PACS

<u>Objectives</u>

At the completion of this lesson, the student radiographer will be able to:
1. Define the term "PACS."
2. Define "teleradiology" and explain its significance relative to the scope of radiography, radiology, and patient care.
3. Describe what is meant by "Filmless Radiology."
4. List five major components of a PACS system.
5. Briefly describe the DICOM organization, and explain the rationale of their formation.
6. Define HIPAA and state two of its objectives.

Outline: PACS

I.   Introduction
      A.   What is PACS?
      B.   PACS Vision
      C.   Key issues to be resolved

II.   Systems and Subsystems
      A.   Teleradiology
      B.   Filmless Radiology
      C.   Interfacing

III. Components of PACS
      A.   Input devices
      B.   Networks
      C.   System and File Servers
      D.   Data compression
      E.   Image Display Workstations
      F.   Image Data Storage
      G.   Interfaces
      H.   Radiology Information Systems (RIS)
      I.   Hospital Information Systems (HIS)

IV.   DICOM & HIPPA
      A.   Health Insurance Portability and Accountability Act (HIPAA)
            1.   Scope of HIPAA
            2.   Patient information privacy issues
            3.   Electronic security issues

Section E

Power Point Presentation

and

Lecture Notes

Lecture Notes CR Radiography

Lesson 1
Historical Development of Computed Radiography

- This module discusses the historical development of computed radiography and compares this relatively new technology to conventional film/screen imaging.

- Descriptions of computed radiography latent image formation and acquisition, image processing and image display technology are presented to provide a basic working knowledge for radiographers using this latest advancement in the imaging sciences.

- Digital images are constructed from numerical data and have been in common use in various areas of medical imaging for many years. Computed imaging systems such as computed tomography (CT) and diagnostic medical sonography imaging have been around for over 25 years, while magnetic resonance imaging (MRI), digital fluoroscopy, and digital subtraction angiography have been commonly used since the 1980's.

- Computed radiography was introduced simultaneously in 1981 at the International Congress of Radiology in Brussels and at the Radiologic Sciences of North America in Chicago. However, widespread adoption of computed radiography for general radiographic imaging lagged behind other computer-driven modalities, primarily because digitization of analog data produced reductions in the quality and quantity of information.

- Technological improvements were needed to meet the quality standards essential for the performance of highly detailed, general radiographic examinations.

- Subsequently, manufacturers' research and development teams focused CR system improvements in three areas:
Enhanced speed and spatial resolution of the CR systems, reduced patient exposure dose, and the augmentation of data storage to provide timely retrieval and communication.

Lesson 1
Principles of Computed Radiography

- Basic principles of digital imaging technology are introduced as well as a distinction of the differences, advantages and disadvantages of computed and conventional radiography.

- Image acquisition, two common image receptors and the image processing system are presented.

- The module concludes with a description of computed radiography image display formats

- After studying the information presented, the learner will be able to:

  - Discuss the historical development of computed radiography.

  - Differentiate between digital and conventional radiographic latent and manifest image production.

  - Specify a minimum of three advantages and one disadvantage of computed radiography.

  - Differentiate between direct and indirect conversion image receptors.

  - Describe photostimulated luminescence phenomenon and explain why it is necessary to produce a CR image.

  - Given a diagram of an imaging plate, correctly identify the various layers of IP construction.

  - Describe each step involved in CR image processing.

  - Specify the most common image display formats utilized with CR systems.

- Digital or Computed Radiography (CR) is a general term used to describe a system that electronically records a radiographic image.

- Computed radiography systems use unique imaging receptors to capture an analog image and sophisticated readers to process the image and convert the information to a digital format.

106

- In conventional imaging, visible details of human structure are recorded on film as bits of analog information; once they are obtained the image cannot be altered.

- Since CR utilizes digital technology, these images may be electronically manipulated to adjust for contrast and brightness. The computer-generated images obtained with CR may be displayed electronically or on film.

Lesson 2
Computers in Radiography

- Basic concepts of computing using large-scale computers and personal computers. Introduction to operating system commands, applications software (word processing, spreadsheets, communications, etc.), and rudimentary programming. Basic computer skills such as use of a mouse and keyboard operations will be covered. This course is required to be able to operate a computer correctly, and to give the student a basic understanding of how computers work.

- Medical Imaging achieved with Digital Computers. Digital computers handle data compsed of definite quantities of information.

- ADC - Analog to digital conversion. The information has been processed by an ADC which converts the analog information to an electronic digital signal. Analog gives continues information (like a mercury thermometer), whereas digital information is given in discrete units (like a digital clock).

- Since CR utilizes digital technology, these images may be electronically manipulated to adjust for contrast and brightness. The computer-generated images obtained with CR may be displayed electronically or on film.

- Binary language - the computer operates on a binary system of numbers, a 2 symbol alphabet: 0 and 1. These are called bits, an 8 bit code is called a byte.

- The computer uses algorithms or mathematical calculations to formulate image construction for the specific type of examination and patient position. When placing the IP in the processor, the radiographer must select the proper processing algorithm on the computer by identifying the anatomic part and radiographic projection of the image.

This is a vital step to ensure accurate computer processing using the correct mathematical calculations.

- Data entered by the radiographer is evaluated, manipulated, and used by the computer to construct a graphic display of pixel values called a histogram. Every image has its own unique histogram.

- When the histogram suggests an incorrect exposure the photo multiplier tube (PMT) adjusts the current to compensate for the exposure error. For example, the PMT will increase the signal when the exposure is too low and will decrease the signal when the exposure is too high.

- Each CR manufacturer indicates the level of x-ray exposure in a different manner. However, each system specifies the expected range of x-ray exposure necessary to produce diagnostic quality images.

- Computerized digital images are displayed on a matrix,(a square series of boxes). The greater the matrix, the better the image resolution.

- The digitized x-ray intensities or pixels (picture elements) are patterned to form the matrix. The pixel is the smallest component of the matrix and the quantity of information in each pixel is determined by the number of bits (binary digits) of information per pixel.

- Each pixel brightness level represents the attenuation characteristics of the corresponding tissue volume in that particular pixel. As mentioned earlier, the computer is capable of displaying over 1000 shades of gray.

- The number and size of the pixels are important in determining the spatial resolution of the digital image. If the image matrix has only a few pixels, the spatial resolution is considered to be poor, which may result in inadequate image quality.

- Density and contrast of the digital images are controlled by varying the numerical value of each pixel. The window level controls the image density, and is a direct relationship. As the number goes up, the density of the image is increased. The widow width controls the contrast, and is an indirect relationship.

Lesson 3
Conventional vs. CR Imaging

- Many similarities exist between computed and conventional radiographic systems.

  Both systems use the same x-ray tube and generator. Both systems require careful selection of technical factors and accurate radiographer positioning skills.

  In addition to using the CR image receptors in a fixed radiographic room, similar to film/screen technology, some computed radiography systems permit easy transport of the image receptor for intraoperative and mobile radiography use.

- Computed radiography offers many advantages over conventional film/screen technology.

- Conventional radiography limits the visibility of a wide range of structures within the same anatomic part, i.e. bone versus soft tissue; whereas, computed radiography, with only one exposure, has the ability to record a wider range of tissues.

- By changing the window width (contrast) and window level (brightness) on the CR image, a clinician can evaluate both the bony structures and soft tissue detail on the same image.

- Conventional radiography also has a limited contrast range based on the attenuation characteristics of the tissues being radiographed.

- Soft tissue structures with similar densities may not be well differentiated on a conventional radiograph due to low subject contrast producing limited shades of gray.

- Digital images provide much wider contrast resolution and can even provide quantitative data on the attenuation characteristics of anatomic tissues.

- Conventional radiography, with its curvilinear film response, requires the optical densities to fall within the straight-line portion of a characteristic curve generally within the 0.5 - 2.5 optical density (OD)

- Computed radiography provides greater latitude in producing an acceptable image.

- CR image receptor response is linear, without a heel (Dmin) or shoulder (Dmax), thus providing greater exposure responsiveness when compared to conventional film.

- Once a conventional radiograph is processed the image is permanent; post processing image enhancements are not possible.

- Capturing the image in an electronic format allows the clinician to alter the scale of contrast and density of the image during each viewing session.

- Computed radiography offers further advantages in image and information management.

- In contrast to electronic information management, conventional images carry significant human resource and financial burdens. For example, operating a large, conventional film library requires a larger pool of clerical staff, greater square footage for film storage and significant man-hours dedicated to film filing and retrieval activities.

- Lost or misplaced films create additional challenges that are absent in the digital image environment. Conventional images "on loan" are difficult to track, while film-tracking challenges are virtually eliminated with electronic imaging.

- Image resolution for conventional and computed radiography vary in different ways. Conventional film/screen technology can resolve between 6 -10 line pairs/mm, whereas, CR is limited to about 2.5 line pairs/mm. Good spatial resolution is important for good image quality and diagnosis.

- Patient dose: There is controversy as to which type of imaging systems provides lower patient exposure. Most CR imaging cassettes are equivalent to a 200-300 speed film/screen combination, whereas, conventional radiography are equivalent to 400 film/screen combinations.

- When comparing individual exposures, less exposure is used per image on conventional film screen exposures. The caveat is that CR is kVp driven, which results in higher kVp, lower mAs; therefore, lower patient dose. Another argument for CR is less repeated exposures are produced, due to the post-processing features of CR, which results in lower patient exposure.

Lesson 4
Photostimulable Phosphor Plates

Currently, two types of imaging receptors are available with a computed radiography system: Direct and Indirect conversion receptors.

Indirect Conversion Receptors

- Photostimulable storage phosphor imaging plates are considered indirect conversion receptors. They utilize a two-step process involving a scintillator and photodetector.

- The x-ray energy strikes the scintillator and is converted to visible light, similar to conventional intensifying screens.

- The photo detector then converts this visible light energy into an electric charge.

- The most common receptor utilized in computed radiography is the photostimulable phosphor plate.

- The imaging plate (IP) is used in place of the film/ screen combination within a specially designed cassette and is comprised of five layers (The top-most layer is a protective layer, generally made of polyethylene terephalate).

- It is a thin, transparent layer used to guard against damage caused by handling the IP.

- The second layer is the photostimulable phosphor layer. serves as the functional layer of the IP by storing most of the energy absorbed from the x-ray exposure.

- Information obtained through the initial stimulus or primary excitation (x-ray exposure) is stored in the phosphor and later "read-out" when light or a secondary stimulus is applied to the phosphor layer.

- This is called a photostimulated luminescence phenomenon and makes energy storage possible within the crystal.

- The phosphor layer is comprised of crystals of barium fluorohalide in combination with a small amount of europium ($BaFx:Eu2$).

- The halides most commonly used in the phosphor are bromide, iodide, and chloride.

- Europium acts as an activator replacing some of the barium atoms and creating a "luminescence-center" in the crystal.

- This is critical because it is the luminescence-center in the crystal that becomes ionized by the radiation (primary excitation) and is the site where energy (information) is stored as a latent image.

- The latent image is formed within the crystal following the transfer of energy by a photoelectric interaction. During image processing, a secondary stimulation created by a laser beam scan of the IP causes the crystal to emit blue-violet light proportionate in intensity to the x-ray energy absorbed.

- It is very important to note that the barium fluorohalide is more sensitive to scatter radiation than conventional intensifying screens phosphors.

- Use of close collimation and a grid are important in obtaining a quality CR image. Increasing the number or size of phosphor crystals will increase the inherent light emitting efficiency;

- It will also decrease image sharpness and increase inherent noise, similar to the same characteristics of intensifying screens.

- The third layer is the supporting layer. By providing rigidity to the IP, it protects the phosphor layer from extraneous forces and shocks.

- The supporting layer is black in color to inhibit reflection of this laser light at the boundary of the phosphor and supporting layers.

- A fourth, backing layer is added for additional protection. The fifth and final layer provides a surface for placement of a barcode label

- The barcode label assigns a specific number to each imaging plate and is necessary for identifying imaging information.

- The imaging plate can retain the latent image for a period of time, but it will lose about 25% of the stored energy within 8 hours. Maximum results are obtained when the image is processed shortly after exposure.

- It should be noted that most CR imaging plates have a relative sensitivity equivalent to 200-300 speed film/screen combinations and may be used for approximately 10,000 images before the image quality begins to degrade.

Lesson 4
Direct conversion systems / Direct Radiography (DR)

- Utilize an x-ray photoconductor to directly convert x-ray photons into an electric charge.

- Both types of receptors send the electric charge to an electronic readout mechanism and an analog-to-digital converter (ADC) to produce a digital image.

- Both systems are capable of producing images with wider exposure latitude than conventional film.

Direct Conversion Receptors

- Use of large-area, flat panel detectors with integrated, thin-film transistor readout mechanisms to be used in conjunction with stationary x-ray equipment.

- Some size limitations exist

- Anticipate image quality outcomes exceeding that of both film/screen receptors and photostimulable storage phosphor receptors because of the direct conversion.

- Direct conversion systems are typically constructed of an amorphous selenium photoconductor on top of an electronic thin-film transistor TFT).

- This allows pixel charge collection and read-out immediately adjacent to the site of x-ray interactions.

- Selenium is used as the photo conducting material due to its high intrinsic spatial resolution and its excellent ability to detect x-rays.

- Prior to exposure, an electric field is applied to the selenium layer. As x-rays are absorbed in the photoconductor, they are converted to electron-hole pairs, which are collected by the transistor.

Lesson 5
Image Storage

- Image storage in an electronic format allows for easier image management.

- Digital imaging systems permit multiple and simultaneous accesses for viewing and interpreting the same image at various locations throughout the medical institution.

- In addition, the electronic format affords rapid and convenient transmission of images to geographic locations extending beyond the confines of the facility

Lesson 5
Absorption Quantum Efficiency

- During image processing, laser light excitation of the phosphor crystals releases the converted x-ray energy stored in the IP as blue-violet light.

- The information stored on the imaging plate is in analog form and is not converted to digital information until the image is processed.

Lesson 5
Digital Image

Digital images are described in terms of numeric values displayed in an array of rows and columns of pixels (picture elements). This array of pixels is termed a matrix

- The pixel is the smallest component of the matrix and the quantity of information in each pixel is determined by the number of bits (binary digits) of information per pixel.

- Corresponding to a specific anatomical location, each pixel represents the x-ray intensity by a numeric value representing a shade of gray

- Each pixel determines the density levels corresponding to a particular area on the image.

- Although the human eye can only distinguish approximately 32 shades of gray, a digital image can display densities ranging from −1000 (air or black areas) to +1000 (bone or white areas).

- Having access to a wide range of densities improves the visualization of anatomic structures, especially those areas with relatively low subject contrast.

- Adjusting the range of densities displayed on the digital image varies the scale of contrast - more density shades yield longer contrast scale while fewer shades produce shorter scales.

Lesson 5
Spatial Resolution

- The number and size of the pixels are important in determining the spatial resolution of the digital image.

- If the image matrix is comprised of few pixels, the spatial resolution of the digital image is poor and results in inadequate image quality.

- Although spatial resolution is important when performing computed tomographic or magnetic resonance imaging procedures, thin slices limit the amount of information required in each image. However,

- When performing conventional imaging, such as chest radiography, the entire body part is imaged at one time; the enormous amount of information captured on a conventional radiograph makes good spatial resolution or detail especially critical.

Lesson 5
Image Quality

- Conventional film/screen technology can resolve between 6-10 line pairs/mm,

- CR is limited to about 2.5 line pairs/mm.

  Since poor spatial resolution may result in a missed diagnosis of an existing pathology, increasing the matrix size for CR is very important.

- Computed radiography requires a minimum matrix of 1024 x 1024 or 1,048,576 pixels to create an acceptable image. In many cases a 2048 x 2048 matrix or 4,194,304 pixels is preferred for diagnostic image quality.

- Compared with CT imaging, use of a 512 x 512 matrix will yield about 0.5 megabytes of information, while the matrix requirements of

computed radiography generate a massive amount of information in the 4-6 megabytes range.

- Today, because of improvements in computer technology, managing images with this massive amount of information is possible at an affordable price. Furthermore, reduced costs of high-resolution monitors positively impacts CR economics. A variety of vendors now offer reasonably priced quality imaging systems.

Lesson 6
Picture Archiving and Communication Systems

- Digital images can be directly transferred to remote monitors or films can be digitized and then sent through a high-speed cable network.

- Images can be transferred via long distance transmissions, or from monitor to monitor within the same area: nursing stations, intensive care units, emergency rooms, and off-site clinicians and radiologists.

- Fully implemented PACS provides acquisition and storage of each medical image in a digital form, without using film

- Provides for immediate interpretation by a radiologist. Resulting in a more accurate and efficient diagnosis for the patient.

- 3 principles are the display system, the network, and storage system.

- The display system of PACS is the CRT monitor - thus resulting in a "filmless system." CRT must be of high resolution, at least 2084 x 2084.

- To compare, present digitally acquired images range from 256 x 256 to 1024 x 1024. Post processing, using the keyboard, can help increase the resolution by using subtraction, edge enhancement, windowing and zoom, among other features.

- To be effective, each workstation should be microprocessor controlled and can interact with each imaging device and a central computer. To provide each interaction, a network is required.

- Network is described as the manner in which many computers can be connected to interact with one another.

- In radiology, the network may consist of PACS workstations, remote PACS stations, a departmental mainframe (radiology information

system - RIS), and a hospital mainframe (hospital information system - HIS).

- The name teleradiology has been given to the process of remote transmission and viewing of images. The American College of Radiology (ACR), in cooperation with the National Electrical Manufactures Association (NEMA), has produced a standard imaging and interface format.

- DICOM - Digital Imaging and Communications in Medicine standard is a system of computer software standards that permit a wide range of digital imaging programs to understand one another.

- DICOM allows sharing of the same computer network and software filing system without conflict.

- Storage system - one justification for PACS is archiving. PACS replaces the film filing system by placing a magnetic or optical memory device.

- Optical disks can accommodate tens of gigabytes of data and images. When a jukebox storage is used, terabytes can be accommodated. The entire file room can be reduced to an archival systems the size of a desk.

POWER-POINT PRESENTATION #1

Computed Radiography & Direct Radiography
Overview with Power Point Presentation

- CR - PHOTOSTIMULABLE PHOSPHOR PLATE
- DR - TFT (THIN FILM TRANSISTOR)
- CR vs. DR Conventional RAD used –
    image acquired in a digital format using an imaging plate rather than film
    imaged captured by plate
    processed in a Digital Reader
    Image then available on a monitor
    hard copy can be made with laser printer

Direct Radiography uses a transistor receiver (like bucky) that captures and converts x-ray energy directly into digital signal that can be seen immediately on video monitor - then sent to PACS/ printer/ other workstations

Image Resolution
CR - can be 2048 x 2048 - image only as good a monitor
525 vs. 1000 line vs. 2000 line etc

more pixels = more memory needed to store
110 films/hr DR - 2560 x 3072 matrix image
ready in 30 seconds

Note: CR 2 -5 lp/mm Conventional Radiography 3-6 lp/mm DR ?
CR Can use standard X-ray Equip
Uses photostimulable plate with barium fluoro halide crystal
can hold image for up to 6 hrs (some say 24 hours)
H&D curve - more info available in the high & low ranges (Merrill's)
Image Reader converts analog image (latent image) on imaging plate to digital - then scanned by laser Image displayed on monitor (replaces view-boxes)
Image enhanced: zoom /contrast/ rotate/

CR - Imaging plate
Looks like a regular x-ray cassette less dose needed ? (tendency to use more due to quantum mottle
phosphor plate inside cassette is removable
(thin -flexible- 1 mm)images can be tailored

DR Initial expense high
very low dose to pt - image quality of 100s using a 400s technique

Computed Radiography & Direct Radiography
(Overview with Power Point Presentation)

What about extremity exposures / portables
Storage /Archiving

CONVENTIONAL RAD
films: bulky
deteriorates over time
requires large storage & expense
environmental concerns

CR & DR
8000 images stored on CD-R
Jukebox storage
no deterioration of images
easy access

Basic Computer Operations
(Overview with Power Point Presentation)

What is a computer ?
A Computer is a made up of a number of functional parts which
    allow the storing of computer programs
    decode instructions within a computer program
    allow the execution of computer programs
    handle information from the user and/or other external
    devices/machines.
    control all the above

Introduction to Computer Architecture
A basic computer consists of the following
    Input
    Screen for Output
    Keyboard/Mouse for
    Input
Base containing:
    On/Off Switch
    Power Supply
    Long Term Storage (Hard Disk)
    Short Term Storage (Memory)
    Engine (Central Processing Unit)

What is computer architecture ?
Computer Architecture is the structure of these functional parts, how they interact and how this interaction facilitates the task of the computer to run programs.

Introduction to Computer Architecture
    Hard Disk, Memory, CPU, Busses
    Input/Output, Peripherals
    Number Systems
    Signals to Numbers
    Binary, Hexadecimal, Octal, BCD, Other Bases
    Introduction to the D6 Computer
    Registers, Memory , Function Keys
    Data Representation
    2's Compliment Representation

Basic Computer Structure

Long Term Storage

All the programs and files are stored on a permanent persistent device
called the hard disk. We can use Windows

Explorer (Win WinNT) to see them

HARD DISK

Permanent Storage

Hard Disk Properties

Magnetic Disk for long term storing of information

Files are "dead" (not running) on the hard disk

Does not need power supply to keep the files

(similar to the floppy disk)

Capacity is huge (Gigabytes)

Speed is slow

(Takes a long time to copy a dead program into the "live" memory)

Memory (Short Term Storage)

The files and programs on the hard disk are there for storage. If we
want to RUN a program we must move it to Memory. We can
see what's in memory (running) using NT's Task Manager.

MEMORY

Temporary Storage

Computer Chips for short-term storage of information

Programs (files) are "live" in memory

Needs a power supply to keep the programs alive. (Switching off the
computer, kills all programs and information in memory)

Capacity is small (Megabytes)

Speed is fast (Once a program has been copied from the
hard disk to memory, it executes a lot faster)

CPU - Central Processing Unit

This is the ENGINE of the computer

The program (instructions) are taken one at a time from memory and
executed at high speed in the CPU.

Memory

Program

(List of Instructions) ONE Instruction

CPU

Arithmetic Logic Unit

Control Unit

HARD DISK

Program X
Programs

Programs are lists of instructions
Set up values
Add, Subtract, Multiply, Divide
Input/Output text
Repeat a number of times
Analogy of Book of Recipes
Recipe Book - Permanent Storage
Photocopy of ONE recipe - Fast Access like Memory

Hard Disk Memory CPU
On the Bus
Information passes from disk to memory to CPU and back
This information passes on a collection of wires
        a collection of wires is known as a bus
        a group of wires used for control is a control bus
        a group of wires for data information is a data bus
        a group of wires for address information is an address bus

Memory
(8 bits wide) CPU
(using 8 bit data) 8 wire DATA BUS

Input and Output
Programs can process information from the user
Input Input information
Pointing information (Mouse)
Words, Numbers, Letters etc. (Keyboard)

Programs can pass info back to the user
Output Output information
Graphics, Documents, Results (Screen)
Graphics, Documents, Results (Printer)

Devices that pass information to the computer or receive information
        from the computer are known as peripherals peripherals

<u>Summary</u>
A Basic Computer System
SCREEN
KEYBOARD MOUSE
HARD DISK (files, progs)
      Memory
      (instructions)
CPU
      (execute instruction)
Bus (wires)
      Output
      Printer
      Output Input

References for Curriculum

American Society of Radiologic Technologist. (2000). *Curriculm draft for radiologic technology*. Minniapolis, MN: Author.

Ballinger, P., & Frank, E. (1999).*Merrill's Atlas of Radiographic Positions and Radiologic Procedures* (9th ed. Vol. 3). St. Louis: Mosby.

Balter, S. (1993). Fundamental Properties of Digital Images. *RadioGraphics, 13*(1), 129-141.

Bushong, S.C. (1997), *Radiologic science for technologists* (6th ed.). St. Louis. MO: Mosby

Carlton, R., & Adler, A. (2001). *Principles of radiographic imaging* (3rd ed.). Albany, NY: Delmar Publishers.

Cesar, L. (1997). Computed radiography: Its impact on radiographers. *Radiologic Technology, 69*(3), 225-235.

Chotas, H. (1999). Principles of digital radiography with large-area, electronically readable detectors: A review of the basics. *Radiology, 210*, 595-599.

Horii, S. C. (1997). A nontechnical introduction to DICOM. *RadioGraphics, 17*, 1297-1309.

Huang, H. (1999). *PACS:basic principles and applications*. New York: Wiley-Liss.

Huda, W. & Szeverenyi, N. M. (1999, February). The filmless radiology department: A primer. *Applied Radiology*, 30-34.

Joint Review Committee on Education in Radiologic Technology [JRCERT]. (1996). *Planning guide for program review: Curriculum and academic practices* [handbook]. Chicago, IL: Author.

Joint Review Committee on Education in Radiologic Technology. (1996). *1996-1997 Computer-based radiography education, 11*, 1998.

Kodak Digital Science. (1996). *Digital Radiography Using Storage Phosphors*. Rochester, NY:Eastman Kodak Co.

Kodak Health Imaging Division. (2000). *Introduction to digital radiography*. Rochester, NY: Kodak, Eastman Co.

Kodak Health Imaging Division. (1999). *Web-based Technology in Healthcare.* Rochester, NY: Kodak,Eastman Co.

Kodak Health Imaging Division. (1996). *The fundamentals of DICOM.* Rochester, NY: Kodak, Eastman, Co.

Kowalczyk, N. (2001). *Principles of computed radiography.* Alberqueque, NM:ASRT

Morrison, C. L. (1999). Telemedicine and teleradiology: implications for radiologic technologists. Retrieved November 18, 2001, from http://www.asrt.org/telemedicine.htm

Nader, J. C. (1995). *Prentice Hall's Illustrated Dictionary of Computing* (2nd ed.). New York: Prentice Hall.

Norris, T. G., (1999). Telemedicine And Teleradiology. *Radiologic Technology, 71*(2), 139-164.

Sabatini, J. (1999, June 28). RT's, teleradiology & the law. *Advance for Radiologic Professionals,* 36-39.

Seibert, J. A. (1999). *Digital Image Acquisition of Projection Radiographs: Computed and Direct Radiography.* Davis, CA: University of California, Davis.

Siegel, E., & Kolodner, R.(2000).*Filmless radiography.* New York: Springer.

Society for Computer Applications in Radiology (SCARS). (1992). *Understanding PACS: Picture Archiving and Communications Systems.* Harrisburg, PA: SCAR Pub.

Staab, E. V. (1993). Computers for Clinical Practice and Education in Radiology. *RadioGraphics, 13*(1), 143-152.

Tateno, Y., Iinuma, T., & Takano, M. (1987). Computed radiography. Tokyo: Springer-Verlag.

REFERENCES

Adler, L. A. (1997). The role community colleges should
    play in job placement. *New Directions for Community
    Colleges, 25* (1), 41-48.

Alexis, M. (2002). *Employment Outlook 1996-2006: A Summary
    of BLS Projections*. Washington, DC: US Department of
    Labor.

American Registry of Radiologic Technology [ARRT].
    (2001)Retrieved on Nov http://www.arrt.org St. Paul,
    Minnesota

American Society of Radiologic Technologist. (1996).
    Educational trends in the radiologic sciences:
    Results of a validation research survey. *Radiologic
    Technology, 68*, 69-79.

American Society of Radiologic Technologist. (2000).
    *Homestudy: Alphabet soup: A guide to resources in
    radiologic technology*. Minniapolis, MN: Author

Badway, N., & Grubb, W. (1997). *A sourcebook for reshaping
    the community college: curriculum integration and the
    multiple domains of career preparation Vol. 1.*
    Berkeley, CA: Office of Vocational and Adult
    Education, National Center for Research in Vocational
    Education.

Ballinger, P., & Frank, E. (1999).*Merrill's Atlas of
    Radiographic Positions and Radiologic Procedures* (9th
    ed. Vol. 3). St. Louis: Mosby.

Balter, S. (1993). Fundamental Properties of Digital
    Images. *RadioGraphics, 13*(1), 129-141.

Berryman, E., & Bailey, R. (1992). The double helix of
    education and the ecomony. *The Institute on Education
    and the Economy.* New York: Teachers College, Columbia
    University.

Blanchard, A. (2000). Contextual teaching and learning.
    Retrieved November 18, 2001, from
    http://www.horizonshelpr.org

Brodhead, W. (1992). A vision for education. *Journal of Vocational Education, 66*(1), 23-25.

Bushong, S.C. (1997), *Radiologic science for technologists* (6th ed.). St. Louis. MO: Mosby

Carlton, R., & Adler, A. (2001). *Principles of radiographic imaging* (3rd ed.). Albany, NY: Delmar Publishers.

Cesar, L. (1997). Computed radiography: Its impact on radiographers. *Radiologic Technology, 69*(3), 225-235.

Clark, S., & Goetz, D. (1996). Unrelieved job stress can lead to burn out. *Radiologic Technology, 68*, 159-161.

David, G. (1998). Management radiology information systems: Evaluation and selection issues. *Radiologic Technology, 69*, 406-410.

Department of Health and Human Services Statistics, 2001). (State of California, Department of Health Services, Radiologic Health Branch [DHS-RHB], 2001).

Dowd, S. (1993). A portrait of the radiographer of the future. *Radiologic Technology, 64*, 166-171

Dowd, S. and Battles, J. (1996).Curriculum development and alignment. *Radiologic Technology, 67,* 263-266

Economic and Work Force Development. (1991). New Directions For Community Colleges [Brochure]. Sacramento: Author.

Employment Development Department [EDD]. (1996). *Labor market information: California-occupational employment projections, 1996-2006.* Retrieved November 18, 2001, from http://www.calmis.cahwnet.gov/file/occproj/ cal$tb6.html

Eubanks, P. (1990). Hospitals Struggle to Respond to the Technologist Shortage. *Hospitals, 64*(14), 34.

Farmer, E., & Key, C. (1997). School-to-work systems and the community college: Looking ahead. *New Directions for Community Colleges, 25*(1), 97-106

Fay, M. (2000). Changing radiologic technology education: Evolution or revolution? *Radiologic Technology, 79,* 667-673

Finch, C. R., & Crunkilton, J. R. (1999). *Curriculum development in vocational and technical education: Planning, content, and implementation.* Boston: Allyn and Bacon, Inc.

Herman, K. (1998, February). Bureau of Labor Statistics, [Bulletin No. 2502]. Washington, DC: US Department of Labor.

Herschbach, D. (1992). Curriculum change in technology education: Differing theoretical perspectives. *Journal of Technology Education, 3*(2), 102-112.

Hirshberg, D. (1991). The role of the community college in economic and workforce development. ERIC Clearinghouse for Junior Colleges Los Angeles CA. (ERIC Document Reproduction Service No. ED339443)

Horii, S. C. (1997). A nontechnical introduction to DICOM. *RadioGraphics, 17,* 1297-1309.

Huang, H. (1999). *PACS:basic principles and applications.* New York: Wiley-Liss.

Huda, W. & Szeverenyi, N. M. (1999, February). The filmless radiology department: A primer. *Applied Radiology,* 30-34.

International Technology Education Association [ITEA]. (2000)*Standard for technological lieteracy:Glossary.* Retrieved November. 3, 2001 from http://www.iteawww.org/TAA/Glossary.htm

Jacobs, J. (1993). Vocational education and general education: New relationship or shotgun marriage? *New Directions for Community Colleges,* 81, 75-84. ERIC Clearinghouse for Junior Colleges, Los Angeles, CA. (ERIC Document Reproduction Service No. EJ464449)

Johnson, S. (1992). Authentic assessment in technology teacher education. *Journal of Epsilon Pi Tau, 18*(2), 8-14

Joint Review Committee on Education in Radiologic
     Technology [JRCERT]. (1996). *Planning guide for
     program review: Curriculum and academic practices*
     [handbook]. Chicago, IL: Author.

Joint Review Committee on Education in Radiologic
     Technology. (1996). *1996-1997 Computer-based
     radiography education, 11*, 1998.

Kerka, S. (1995). Authentic assessment in vocational
     education. *Trends and Issues Alert* Office of
     Educational Research and Improvement, U.S. Department
     of Education. (ERIC Document Reproduction Service No.
     ED399998)

Kodak Digital Science. (1996). *Digital Radiography Using
     Storage Phosphors*. Rochester, NY:Eastman Kodak Co.

Kodak Health Imaging Division. (2000). *Introduction to
     digital radiography*. Rochester, NY: Kodak, Eastman
     Co.

Kodak Health Imaging Division. (1999). *Web-based
     Technology in Healthcare*. Rochester, NY:
     Kodak,Eastman Co.

Kodak Health Imaging Division. (1996). *The fundamentals of
     DICOM*. Rochester, NY: Kodak, Eastman, Co.

Kowalczyk, N. (2001). *Principles of computed radiography*.
     Alberqueque, NM:ASRT

Little, J. (1992). Stretching the subject: The subject
     organization of high schools and the transformation
     of work. National center for research in vocational
     education. Berkeley, CA: (ERIC Document Reproduction
     Service No. ED359365)

Morrison, C. L. (1999). Telemedicine and teleradiology:
     implications for radiologic technologists. Retrieved
     November 18, 2001, from
     http://www.asrt.org/telemedicine.htm

National Commission of Secondary Vocation Education
      [NCSVE]. (1994). Integration of academic and
      vocational education: Joint effort of vocational and
      academic educators to bridge the gap between
      theoretical and practical education. Columbus, OH:
      Author.

Norris, T. G., (1999). Telemedicine And Teleradiology.
      Radiologic Technology, 71(2), 139-164..

Radiologic Technology Educators of California (RTEC).
      (2001).*The Fourm,*Retrevied November 30, 2001, from
      http://www.rteccalifornia.org/thefourm/neweletter.

Rogers, A., Tilson, E., & Cross, D. (2000). Competency
      based testing. *Radiologic Technology, 72,* 487-490.

Rosenfeld, M., Ottoman, P., & Leung, S. (1999). *The
      practice of radiography: A study of clinical
      activities and knowledge areas for the entry-level
      radiographer conducted on behalf of the American
      society of radiologic technologist* [Handbook].
      Minniapolis, MN: Educational Testing Service.

Sabatini, J. (1999, June 28). RT's, teleradiology & the
      law. *Advance for Radiologic Professionals*, 36-39.

Seibert, J. A. (1999). *Digital Image Acquisition of
      Projection Radiographs: Computed and Direct
      Radiography.* Davis, CA: University of California,
      Davis.

Shaver, V. (2001). RT learning styles – what is the best
      way to teach and learn? *RT Image Newsmagazine,
      14*(32), 23-27

Sinclair-Bell, R., & Mitchell, R. (2001). Competency-based
      versus traditional cohort-based technical education:
      a comparison of students' perceptions. *Journal of
      Career and Technical Education, 17(1).* Retrieved
      December 5, 2000, from
      http://scholar.lib.vt.edu/JCTE/v17n1/pdf/bell.

Sanchez, T.(1999). Techniques and the filmless radiology
      department: When digital means higher radiation
      exposure. *ASRT Scanner, 32 (3)*26-29

Siegel, E., & Kolodner, R.(2000).*Filmless radiography.* New York: Springer.

Society for Computer Applications in Radiology (SCARS). (1992). *Understanding PACS: Picture Archiving and Communications Systems.* Harrisburg, PA: SCAR Pub.

Sparks, L. (2000). Defining the educated professional. *Radiologic Technology, 71,* 599-601.

Sparks, L., & Greathouse, J. (2001), Expanding the boundaries. *Radiologic Technology, 72,* 284 – 288

Staab, E. V. (1993). Computers for Clinical Practice and Education in Radiology. *RadioGraphics, 13*(1), 143-152.

Striplin, J. (2000). A review of community college curriculum trends. ERIC clearinghouse for junior colleges Los Angeles CA. (ERIC Document Reproduction Service No. ED427251)

Tateno, Y., Iinuma, T., & Takano, M. (1987). Computed radiography. Tokyo: Springer-Verlag.

Teahen, R. (1996). Curriculum models: Integration of academic and occupational content. ERIC Clearinghouse for Junior Colleges, Los Angeles, CA. (ERIC Document Reproduction Service No. ED399998)

Terrazas, R. (2000).The Life of Ed Jerman. *Radiologic Technology,* 68, 325 – 332.

Tilson, E., Stickland, G., DeMarco, M. L., & Gibson, D. (2001). Online teaching: Design and Techniques. *Radiologic Technology, 72,* 563 – 570.

U.S. Department of Education Office of Vocational and Adult Education and the National School to Work Office. (2000). Contextual Teaching and Learning: Helping students make the connection. Retrieved: November 20, 2000, from http://www.contextual.org

U.S. Department of Education. (2000). *Carl D. Perkins, Educational, vocational act.* Retrieved December 5, 2000, from http://www.ed.gov/offices/OVAE/VocEd/InfoBoard

U.S. Department of Health and Human Services. (2001). *Report of the National Commission on Allied Health.* Washington, DC: Health Resources and Services Administration.

U.S. Department Of Labor, (1992). *The Secretary's Commission On Achieving Necessary Skills [SCANS] : A scans report for America 2000*: Washington, D.C. Retrieved December 5, 2000, from http://www.scans.jhu.edu/NS/HTML/Current.htm

Van Valkenburg, J., Veale, B., Cladwell, S., Lampingnano, J., & Harifield, K. (2000). Educational programs in radiologic technology. *Radiologic Technology, 71,* 525-534

Weinbaum, A., & Rogers, A. M. (1995). *Contextual learning: A critical aspect of School-to-Work transition programs.* Washington, DC: Academy for Educational Development.

Weinstein, D. (1986). Administrator's guide to curriculum mapping, A step by step process. Englewood Cliffs, NJ: Prentice-Hall Inc.