Videofluoroscopic Swallowing Studies

A web-based continuing education course prepared by:

Technical Components of Videofluoroscopy: Image Acquisition Rate and Mode

LENGTH: 60 minutes

OVERVIEW:

This module will cover the technical components of videofluoroscopy. The goal of this module is to empower the learner to better understand how to conduct the most efficient videofluoroscopy exam, to understand the pros and cons of different settings, to read the manuals and check image acquisition rate on the equipment in use, and to have conversations with radiological personnel that will help the clinician make clinical decisions that best serve their patients.

Learning Objectives:

At the end of this module, the clinician learner will be able to:

1) Describe the difference between continuous and pulsed fluoroscopy
2) Describe the difference between pulse rate and frame rate
3) Discuss the relative pros and cons of image acquisition rates of 30 and 15 images per second
4) Describe the ALARA principle and how different image acquisition rates meet or do not meet the intent of this principle
5) Identify the impact on radiation exposure of geometric or electronic image magnification
6) List technical components of videofluoroscopy, other than pulse rate, which can be modified in order to reduce radiation exposure to the patient

Overview: Technical Components

- Current guidelines for VFSS settings
- VFSS basic components
- Fluoroscope settings
  - Image acquisition rate and mode
  - Effect of frame rate on judgments about swallowing function
  - Output vs capture
- Live image stream settings
- Video capture and archiving
  - Frame rate
  - Recording systems, software
- Best practice recommendations for VFSS settings

The Challenge

- You want to capture the *highest temporal resolution possible* (i.e. unique images per second)
- BUT many factors can influence this

The Challenge

Even when people think
they are getting
30 frames per second,
the truth is often different!

VFSS technical guidelines

- Regulatory bodies provide some guidance
- United States: ASHA (2004)
  - exam should be *recorded* at 30 frames per second (fps)
- Ontario: CASLPO (2007)
  - recommend *recording* at 30 fps
- Alberta: ACSLPA (2013)
  - recommend continuous fluoro *recording* at 30 fps

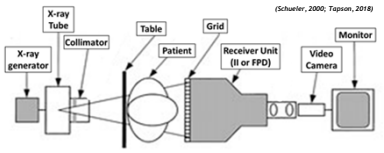
Optimal Image Acquisition Rate

- Since 2007, questions regarding optimal image acquisition rate have been the focus of research conducted by:
  - Professor Bonnie Martin-Harris
  - Professor Heather Bonilha
  - Professor Rosemary Martino
  - Professor Catriona Steele
- It is common for clinicians to seek guidance regarding frame rate.

CASLPO PSG on VFSS

- CASLPO Standard J.4.b.ii
  - SLPs must collaborate with appropriate radiological personnel in the performance of VFSS exams.
  - Performance of a VFSS without radiological personnel present is not permitted.
  - The SLP should strive to limit radiation exposure to the *lowest reasonably achievable* amount, while seeking to obtain sufficient information to define the nature of the patient's/client's swallowing difficulties.

Components of Fluoroscopy Systems



- X-ray generator
- X-ray tube
- Collimator
- Automatic brightness control
- Antiscatter grid
- X-ray receiver unit (image intensifier or flat panel detector)
- Aperture & camera

(Zarzour, Johnson, and Canon, 2018)

Pulse Rate vs Frame Rate

- Pulse rate refers to the number of bursts of radiation that are emitted per second by the fluoroscope (i.e. the radiation beam itself)

Pulse Rate vs Frame Rate

- Frame rate refers to the number of images per second that are captured by the recording system

Fluoroscope Considerations

- Magnification/Zoom
- Collimation
- Imaging mode (continuous vs. pulsed)
- Image spatial resolution (pixel h x w)
- Brightness control
- Timers/warning bells

Geometric Magnification

- Geometric magnification
  - created by moving the object being imaged towards the x-ray tube and away from the detector, while maintaining a fixed distance between tube and detector
  - results in the projected image of the object occupying a larger area of the detector
  - also results in increased dose for the patient, due to the inverse square law

(Ingleby, 2018)

Electronic Magnification

- Electronic magnification
  - available with image intensifiers
  - a smaller area of the input phosphor is imaged onto the output phosphor, resulting in true magnification
  - the dose rate is increased in order to maintain constant brightness at the output

(Ingleby, 2018)

Magnification vs Optical Zoom

- Flat panel detectors (FPD) use a form of optical zoom to magnify
  - no actual increase in spatial resolution
  - rather, a portion of the acquired image is shown over a larger portion of the display
  - when zoomed, noise in the image is more obvious
  - dose is thus increased to reduce this noise level
    - the increase in dose is much less with a flat panel detector than with an image intensifier

(Ingleby, 2018)

Collimation

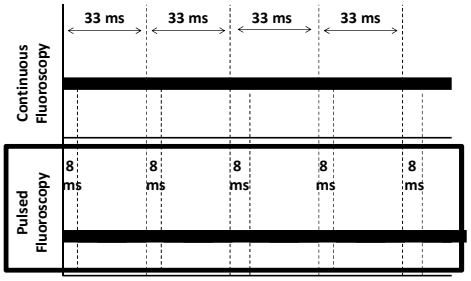
- Collimators are like shutters that limit the x-ray field to the size required for the exam
  - typically adjustable lead blades attached to the tube port
  - automatic when operator selects a field of view
- Benefits:
  - reduction in patient dose
  - improvement of image contrast due to a reduction in scattered radiation

(Dance et al, 2014; Gingold, 2014)

Continuous vs Pulsed Radiation

- Traditional fluoroscopy was continuous (i.e., the beam was either on or off)
- New generation fluoroscopy offers the option of dividing that radiation beam into small packets called pulses
  - the number of pulses that are delivered per second can be specified (30, 15, 7.5, 4, etc.)

Continuous vs Pulsed Fluoroscopy

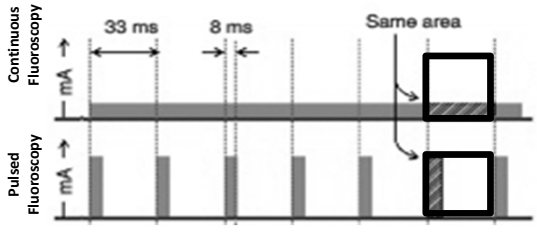


Pulsed vs Continuous

- Additional potential benefit of pulsed fluoroscopy is that the recording is less susceptible to blur from motion artifact

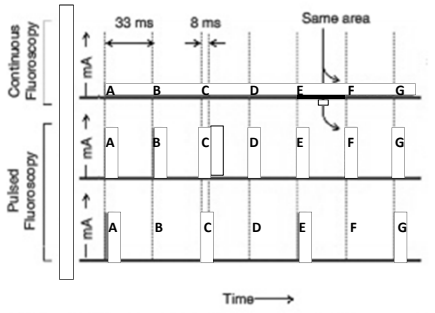
(Schueler, 2000; Cohen, 2009; Bushberg, Seibert, Leidholdt, & Boone, 2012)

Continuous vs Pulsed Fluoroscopy



(Bushberg, Seibert, Leidholdt, & Boone, 2012)

Continuous vs Pulsed Fluoroscopy



(Bushberg, Seibert, Leidholdt, & Boone, 2012)

Image Acquisition Rates

- It is also possible for the *frame rate* of the recording equipment to differ across systems:
  - North American TVs: 30 frames per second NTSC
  - European TVs: 25 frames per second (PAL)
  - Current computer graphics cards: higher rates
  - PACS systems: frequently lower than 30 fps

Fluoroscope settings → Live image stream → Video capture and archiving → Video analysis

How many ACTUAL images will you get per second?

Fluoroscope generated	Capture Frames/sec	Images per second?
30	30	**30**
15	30	**15** (pairs)
7.5	30	**7.5** (sets of 4)
30	7.5	**7.5** (sets of 4)

Output vs Capture

Fluoroscope generated	Capture Frames/sec	Images per second
continuous	25	25
30	25	25 (5 missing)
15	25	15 (+10 duplicates)
25	30	25 (+5 duplicates)

Frame Rate and Inter-Rater Agreement in VFSS Interpretation

- Inter-rater agreement is reported to be higher when there are only 15 images per second.
  - There is less opportunity for disagreement across raters when fewer images are being reviewed.
  - The finding is not dissimilar to the report that inter-rater agreement regarding penetration-aspiration is higher when binary decisions are made compared to the full 8-point Penetration-Aspiration Scale.

(Steele, 2015)

Representation of Risk

- The usual duration of VFSS is ~2mins
- The average duration of a meal is 20-30 mins
- People often eat 3 meals as well as snacks throughout a day

- If 1 pen/asp event is observed in a 2 min VFSS sample, consider that this one observation over 2 mins may be occurring 10-15x/meal!

(Barkmeier-Kraemer, 2018)

Live Image Stream Settings

- Last image hold/video looping
- Display refresh rates
- Recursive filtering
- Signal degradation
- Chain of processing
- Synchronization

Video Loop

- A video loop stores a set number of frames in a working memory on the fluoroscopy equipment.
- If the save function is not used, the video loop will drop the earliest frames in the loop as it captures new frames on the opposite end

Image Distortions: Recursive Filtering

- Adds a portion of the previous image over top of the previous image
- Leads to potential distortions
  - Blurred images
  - Ghosts
  - Impossible distortions
- Some distortions visible in real time
- Settings determined on the fluoroscope by the manufacturer

(Bushberg, Seibert, Leidholdt, & Boone, 2012; Bronzino, 2006; Nickoloff, 2011)

Signal Degradation

- Multiple factors contribute to the integrity of the signal throughout the process
  - Video splitters
  - Lengths of cable
  - Chain of processing

Recording

- Different types of recording
  - PACS
  - Stand alone DVD recorder
  - Computer running capture software (Pentax, TIMS DICOM)
- With or without downscanner
  - Mismatches in rate resulting in interpolation, duplicates
- Saving/memory/processing
- Compressors, codecs
- Replay possibility (frame by frame)

PACS

Picture Archiving and Communication Systems

- Digital fluoroscopy stores a series of individual images to an electronic file.
  - They are stored on a central hub and accessible to users via the PACS network.
- The system can link information from the image to other associated files (e.g., patient ID).
- However; it may limit to < 30 images/s.

Video Capture: Software Limitations

- Kay Pentax DSW
  - No optional settings
  - Archives files as AVI using 'dvsd' video compression; this is the highest video quality you can obtain on the system
  - If compression is required for storage size/end user computer capabilities, quality degrades further (available if needed)
- TIMS DICOM
  - Saving/archiving options available
  - Options to choose colors, bits per pixel, compression
  - Can set up a custom "profile" for VFSS exams

Video Capture: Software

- Know your system settings and who to contact to set them up
  - Configure your setup for optimal image quality

Compression and Downscanning

- Systems may compress a recording due to space limitations
  - Compression may result in loss of image quality
- Consider the need for a supplementary recording device to retain full resolution without compression
- If a downscanner is used, synchronization of signals is critical

Compression

- Container:
  - what holds the grouping of compressed video as defined by the codec; how the data is organized inside the file
  - also referred to as a format
  - takes care of packaging, transport, and presentation
  - usually represented by a file extension
- Example:
  - MPEG4 container is usually represented by a .mp4 file type
- Format examples:
  - .mpg, .avi, .wmv

Compression

- Codec:
  - a method for encoding and decoding data
  - more specifically, a protocol for compressing data, especially video
- Selecting a codec depends on several factors:
  - target file size
  - output quality
  - delivery method
- Examples: DivX, H.264, MJPEG

Compression Summary

- Choices in format, file type MAY impact spatial and temporal resolution or integrity of the time sequence of images for replay
- Know your system
- Optimize for image quality and end user computer

Recommendations for Best Practice

- Image acquisition rates likely to be optimal in terms of sensitivity to penetration-aspiration:
  - 30 images per second
  - when generated using pulse rates of 30 pulses per second and
  - frame rates of 30 frames per second
- Image acquisition rates below 15 images per second are likely to be inadequate to capture important events in swallowing.

Recommendations for Best Practice

Confirm settings at each stage:

1. fluoroscope
2. video graphics card on the fluoro monitor
3. video capture device/software
4. video file saving settings (CODEC, etc.)
5. processor and graphics capability of computer used for viewing
6. ability to review frame-by-frame (software, network access)
7. ambient lighting when reviewing the video

Recommendations for Best Practice

- Use the least magnification necessary
  - as a rule, patient dose rises dramatically with magnification
- Collimate the beam to radiate the smallest field necessary
  - improve image contrast
  - lowers the dose to the patient and clinician
- Minimize beam-on time
  - use “last image hold” and tap to refresh between events
- Be cognizant of dose
  - use a standardized protocol that allows you to answer your question in the fewest tasks possible

(Anderson & Leidholdt, 2013)

Pediatric Fluoroscopy

- Use alternatives to x-ray whenever possible
  - Radiation at an early age is more likely to result in cancer later in life
- Include the family, create a child-friendly environment
  - Reducing child anxiety and increasing cooperation can result in improved exam quality and lower dose to the child (but may involve dose to a familiar feeder)
- Communicate frequently and clearly
  - Let persons attending to the child know when to step back from the table

(Anderson & Leidholdt, 2013)

Pediatric Fluoroscopy

- Select appropriate imaging mode
  - In pediatric pulsed fluoroscopy, the pulse length is reduced to less than 5msec to sharpen the image
- Avoid magnification
  - Rather than zooming in to observe small anatomy, consider a large display monitor or enlarge the image post-processing instead
- Use dose sparing techniques
  - As with adults, minimize fluoro time, utilize collimation, last image hold, low pulse rates, and short patient-to-detector distance

(Anderson & Leidholdt, 2013)

Pediatric Fluoroscopy

- Contact the technical rep to ensure pediatric settings are supported by your equipment

(Anderson & Leidholdt, 2013)

Goal

The ultimate goal is to
conduct a videofluoroscopy using
settings that enable you to capture
the necessary medical information to
answer your questions,

while being responsible about
limiting unnecessary radiation exposure.

Key Messages

- Existing regulatory guidelines around VFSS image acquisition may not accurately reflect current best practice.
- Judgments made in the VFSS suite during the procedure are not likely sufficient to capture transient swallowing events.

Key Messages

- Our responsibility with regards to radiation exposure is to adhere to the ALARA principle: *as low as reasonably achievable*.
- Settings on a fluoroscope can influence the amount of radiation exposure to the patient and clinician.

Key Messages

- Traditional fluoroscopy was typically continuous, producing a steady stream of radiation.
- New generation fluoroscopy can deliver pulsed fluoroscopy, specified by the number of pulses per second.

Key Messages

- Pulsed fluoroscopy benefits:
  - *potentially* involves less radiation exposure
  - less susceptible to blur from motion artifact
- The duration of the pulse, as well as the strength of the dose of radiation in each pulse needs to be considered.
- Image quality is directly related to dose.

Key Messages

- Pulse rate:
  - the number of bursts of radiation that are emitted per second by the fluoroscope
- Frame rate:
  - the number of images that are recorded or stored per second on the recording system
  - can be influenced by the monitor display as well as the recording system storage capacity

Key Messages

- Controlling for both pulse rate and frame rate is important to ensure both synchronization and adequate number of images in the end product for reviewing.
- It is important to understand how to have the system you are using configured for optimal image quality.

Key Messages

- 30 unique images is currently understood to be the optimal number of images per second.
- Image acquisition rates below 15 images per second are inadequate in terms of sensitivity for detecting penetration-aspiration.
- Research demonstrates that there is a loss in diagnostic accuracy at lower image acquisition rates.

Key Messages

- Dose-sparing recommendations for VFSS:
  - Use the least magnification necessary
  - Collimate the beam to radiate the smallest field necessary
  - Minimize beam-on time
  - Be cognizant of dose
  - Use a standardized protocol

Key Messages

- Pediatric-specific VFSS recommendations:
  - Use alternatives to x-ray whenever possible
  - Create a child-friendly environment
  - Select appropriate imaging mode/reduce pulse length
  - Avoid magnification
  - Use dose sparing techniques including minimizing fluoro time, collimation, last image hold, low pulse rates, and short patient-to-detector distance
  - Contact the technical rep to ensure pediatric settings are supported by your equipment

(Anderson & Leidholdt, 2013)

KNOWLEDGE CHECK

1. **Which of the following statements is true?**

   A Judgments made in the VFSS suite during the procedure are likely sufficient to capture transient swallowing events.

   B Judgments made in the VFSS suite during the procedure are not likely sufficient to capture transient swallowing events.

2. **True or false? Frame rate refers to the number of images per second that are shown on the video monitor.**

   A True

   B False

3. **Which best completes this statement? The number of frames available to review on a VFSS recording is a direct result of:**

   A the frame rate of the recording system

   B the lowest number of frames both generated and captured at any point in the VFSS

   C the pulse rate of the fluoroscope

   D the highest number of frames both gene rated and captured at any point in the VFSS

4. **Which of the following contributes to reduction in radiation dose for the patient?**

   A Geometric magnification

   B Highest available electronic magnification mode

   C Optical zoom via a flat panel detector

   D Collimating the beam

5. **True or false? Image acquisition rates below 15 images per second are likely to be adequate to capture important events in swallowing.**

   A True

   B False

6. **The ultimate goal is to conduct a VFSS exam using settings that enable you to capture the necessary medical information to answer your questions, while:**

   A being responsible about limiting unnecessary radiation exposure.

   B creating a family-friendly environment.

   C being mindful of the recommendations made by provincial regulatory bodies.

Answer key found on the following page.

KNOWLEDGE CHECK ANSWER KEY

1. B Judgments made in the VFSS suite during the procedure are not likely sufficient to capture transient swallowing events.

2. A True

3. B the lowest number of frames both generated and captured at any point in the VFSS

4. D Collimating the beam

5. B False

6. A being responsible about limiting unnecessary radiation exposure.

EXPAND YOUR KNOWLEDGE

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Resources:

- Image Wisely www.imagewisely.org
- An initiative of the American College of Radiology, Radiological Society of North America, and the American Association of Physicists in Medicine. It provides information for patients, and makes recommendations to physicians for reducing radiation dose in adult medical imaging.
- Image Gently www.imagegently.org
- The Alliance for Radiation Safety in Pediatric Imaging (Society for Pediatric Radiology, AAPM, ACR, and American Society of Radiological Technologists) provides radiation safety guidance for pediatric imaging, including fluoroscopy, with information for parents.
- IAEA www.iaea.org
- The International Atomic Energy Agency provides educational resources on many topics of radiation safety, including fluoroscopy.
- NCRP www.ncrponline.org
- The National Council on Radiation Protection and Measurements offers publications on a variety of radiation safety issues.
- AAPM www.aapm.org
- American Association of Physicists in Medicine publishes technical standards for medical imaging.
- ACR www.acr.org
- The American College of Radiology offers appropriateness guidelines and practice standards in radiology.
- ACC www.cardiosource.org
- The American College of Cardiology provides appropriate use criteria and practice standards in cardiac imaging.
- SIR www.sirweb.org
- The Society of Interventional Radiology publishes practice standards for interventional procedures, including radiation safety.