AAPM Computed Tomography Automatic Exposure Control Education Slides
GE

Many of the terms used in these slides can be found in the CT Terminology Lexicon

http://www.aapm.org/pubs/CTProtocols/documents/CTTerminologyLexicon.pdf

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Motivation

- These slides are provided to aid in understanding the factors that affect performance of Automatic Exposure Control, specifically image quality and radiation dose, in CT studies

Outline

- Effect of CT Localizer on AEC
- Image quality reference parameter for AEC
- Effect of patient size on AEC
- Effect of scanned anatomy
- Effect of first or expected reconstruction settings
- Advanced AEC features

Effect of CT Localizer

- The CT localizer(s) provide the initial data to inform the behavior of the AEC
- The apparent size of the patient on the localizer(s) or the measured attenuation are used to set the initial dose level for the exam
- The localizer(s) may also be used to adjust the longitudinal or angular tube current modulation
- The use of multiple localizers and the order of their acquisition may affect the behavior of the system's AEC

Effect of CT Localizer – GE Healthcare

- If only one localizer is acquired, the choice of the localizer (AP vs. Lateral vs. PA) impacts AEC calculations
  - Localizers acquired from a lateral perspective are more robust to the effects of suboptimal patient centering, therefore the estimation of the patient size and resulting CTDIvol for the ensuing diagnostic scan is more consistent with a lateral localizer
- If two localizers are acquired, the order of the localizer (AP + LAT vs LAT + AP) impacts AEC calculations
  - The most recently acquired localizer has sole influence on the CTDIvol for the subsequent AEC-based diagnostic scan

Effect of CT Localizer – GE Healthcare

- The scanning parameters (e.g. tube voltage, mA) of the localizer does not impact AEC calculations
  - The estimation of patient size from the localizer is designed to be robust to a wide range of patient sizes and shapes across a wide range of scout exposures
  - The very largest patients imaged at the lowest exposures may result in a relatively low estimate of size, resulting in under-dosing of the patient habitus for the diagnostic scan
  - This emphasizes the need for the localizer CTDIvol to be adequately sized to the patient
  - Advice on the appropriate exposure per patient size is included in the accompanying technical documents of the CT scanner

Effect of CT Localizer – vendor recommendations GE Healthcare

- For head/neck exams it is recommended to use:
  - Two localizers
  - Lateral localizer, if only one localizer is used
  - AP/PA first, if two localizers are used
  - Fixed tube voltage for localizer
  - A minimum of 100/120 kV and 10/20 mA on an average size adult patient for AP/PA and lateral, respectively
- For chest/abdomen/pelvis exams it is recommended to use:
  - Two localizers
  - Lateral localizer, if only one localizer is used
  - Lateral first, if two localizers are used
  - Fixed tube voltage for localizer
  - A minimum of 100/120 kV and 10/20 mA on an average size adult patient for AP/PA and lateral, respectively

Effect of CT Localizer – GE Healthcare

- Mis-centering of the patient impacts AEC calculations
  - This issue occurs for localizers acquired from the anterior-posterior direction.
  - As the patient approaches the focal spot of the x-ray tube, the estimated size increases relative to the centered habitus, and *vice versa* for a patient centered low relative to isocenter
- If a patient appears mis-centered in the localizer, the operator can judge the centering of the patient from the console and cannot compensate for the mis-centering without entering the scanner room
  - GE's Patient Centering feature provides graphical quantitative and directional feedback on patient centering, and relies on the technologist adjusting the patient cradle in response to this feedback
  - GE's Patient Centering feature is currently found on the Revolution Ascend, Revolution CT, and Revolution Apex

Effect of CT Localizer – GE Healthcare

- Once the patient miscentering has been corrected, it is recommended that new localizer(s) be acquired for accurate AEC calculations
  - Localizers acquired from the Lateral perspective are relatively immune from vertical miscentering
  - If the user follows the direction of the patient centering and the patient habitus is now at the correct height, and if an ensuing scout is acquired from the orthogonal anterior-posterior direction, then typically no repeat of the current lateral localizer is required for accurate AEC calculations

Effect of CT Localizer – GE Healthcare

- If the prescribed CT scan range exceeds the range of the acquired localizer, the AEC algorithm:
  - The AEC algorithm uses the same AEC-derived technique for the scan range beyond the localizer as the closest location included within the scan range of the acquired localizer
  - This same methodology is followed by all GE AEC algorithms across the GE CT product line

Image quality reference parameter for AEC

- The image quality reference parameter for AEC is generally a measure of image quality in the reconstructed images
- The image quality reference parameter for AEC has a unique relationship with both tube output and patient size
- Specifically, the Image quality reference parameter is used together with the patient attenuation profile (as estimated by the CT localizer) to determine the tube output for a particular exam
- The operation of the AEC may be independent of the reconstruction parameters, or related to them

Image quality reference parameter(s) for AEC – GE Healthcare

- The primary image quality reference parameter for AEC for this manufacturer is called Noise Index
  - The Noise Index is an index of the noise (pixel standard deviation) in a region of interest of uniform tissue in the reconstructed image
  - In the AEC feature across all GE CT products, the combination of estimated size of the patient anatomy in addition to other parameters like slice thickness, pitch, and rotation time results in a unique tube output for the prescribed Noise Index

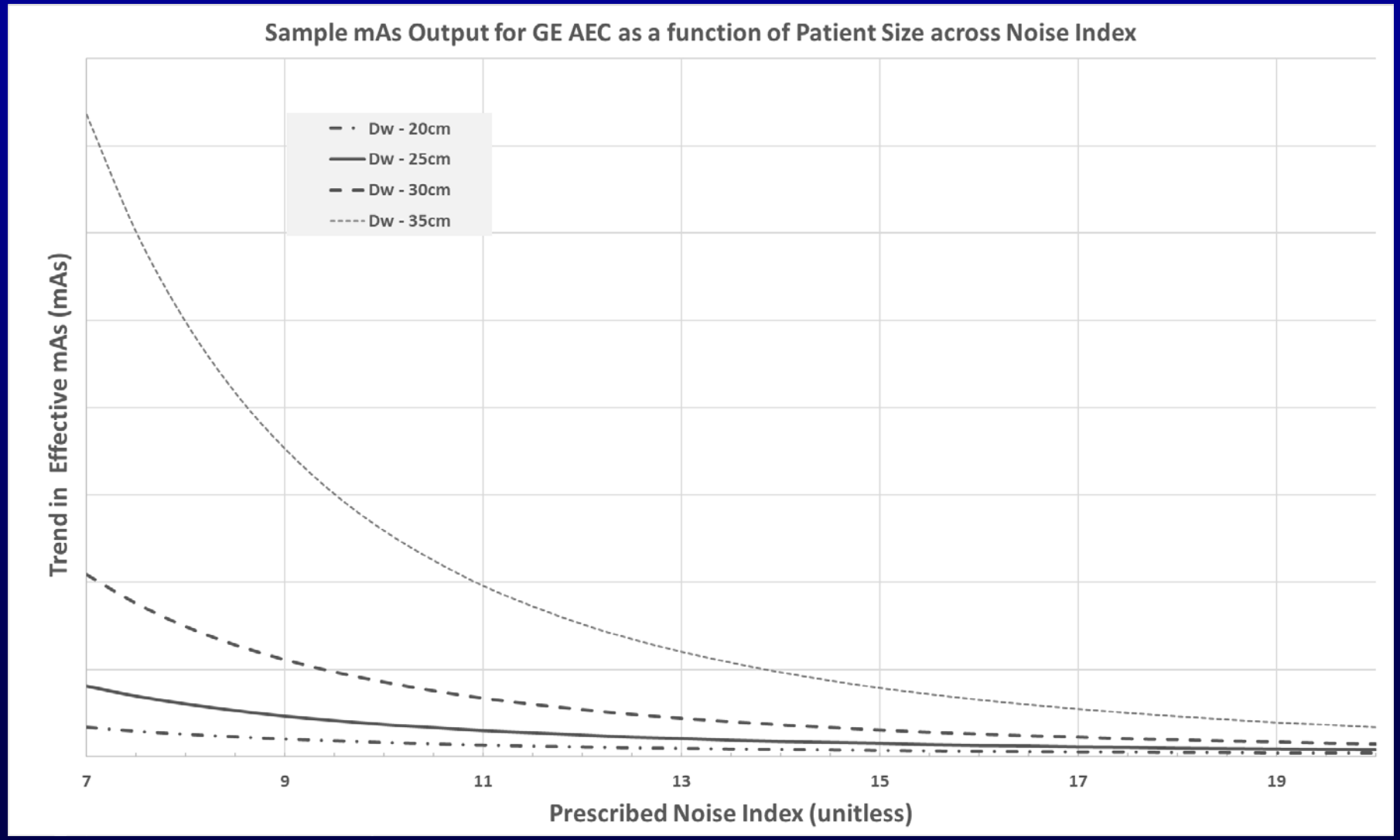
- For scans that do not use Auto Prescription, AEC calculation does not use a reference patient size.
- For scans that use Auto Prescription with Size Adjusted Noise Index, a Reference Patient Size is used
  - Reference Patient Size is 28.9 cm Water Equivalent Diameter (approximately 58 cm AP + LAT, 70-75 kg)

Effect of image quality reference parameter for AEC – GE Healthcare

- The tube output (i.e., effective mAs) has the following relationship with the image quality reference parameter for AEC (all other factors being equal):
  - All GE CT systems adjust the tube output to maintain consistent image quality across the imaged volume
  - In GE AEC features contained in older CT products, the mA typically follows an inverse square relationship to the prescribed Noise Index
  - In the Revolution Apex and Revolution CT, the tube output follows a more complex non-linear relationship that is a challenge to parametrize under all use case scenarios

Effect of image quality reference parameter for AEC – GE Healthcare

- GE's AEC algorithm attempts to maintain constant image noise across all anatomy sizes, hence the exponential trend in mAs a function of changing patient size for the same NI target.
- The plot opposite illustrates the trend in effective mAs as a function of prescribed Noise Index for a typical Body technique.
- The mAs required to achieve constant image noise increases as a function of decreasing prescribed NI and increasing anatomy size

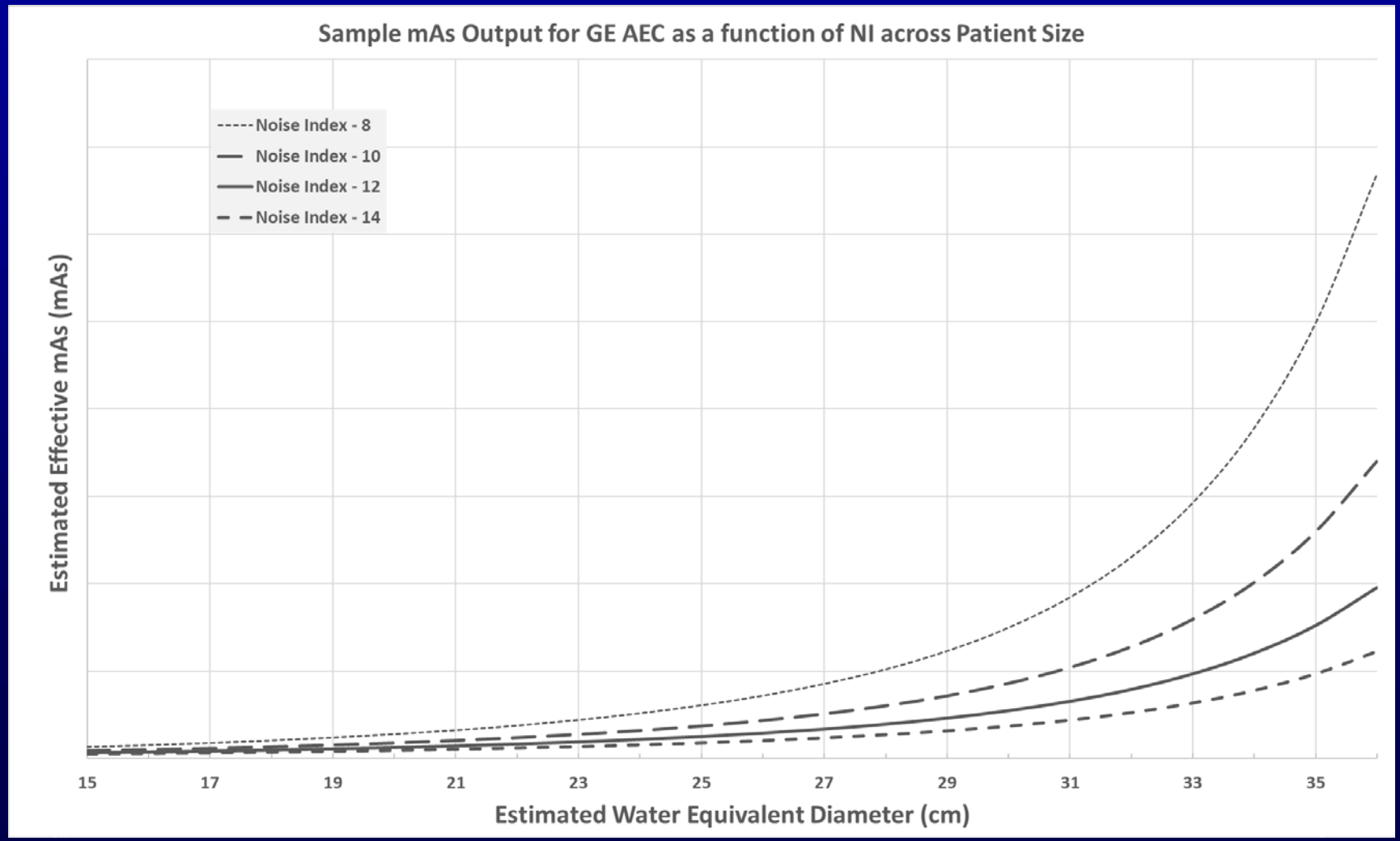


Effect of patient – GE Healthcare

- The tube output (i.e., effective mAs) has the following relationship with the size of the patient (all other factors being equal):
  - GE's AEC algorithm attempts to maintain constant image noise across all anatomy sizes, hence the exponential trend in mAs a function of changing patient size for the same NI target.

Effect of patient size – GE Healthcare

- The plot illustrates the trend in effective mAs as a function of patient size for a typical Body technique.
- The mAs required to achieve constant image noise increases as a function of increasing anatomy size and decreasing prescribed NI



Effect of scanned anatomy – GE Healthcare

- The tube output (i.e., effective mAs) is independent of the organ or anatomy being scanned (all other factors being equal)
  - In general the tube output is independent of the organ being scanned
  - In systems with the Organ Dose Modulation feature enabled, tube output is affected by the user selection of the scanned field of view (SFOV), specifically influencing the amount and angular extent of tube current reduction
  - In Revolution Apex and Revolution CT system, the tube output is dependent on anatomy in protocols that prescribe a cardiac-specific SFOV
  - Further details are available in the technical documents that accompany the CT scanner

Effect of first or expected reconstruction settings – GE Healthcare

- The tube output is affected by the first/expected reconstruction for that protocol (all other factors being equal):
  - The operation of the AEC across all GE CT systems is related to reconstructed slice thickness
  - For Revolution CT and Revolution Apex AEC only, tube output is also impacted by ASiR-V level of primary reconstruction
  - Secondary or subsequent reconstruction settings have no impact on tube output

Effect of first or expected reconstruction settings – GE Healthcare

- In Revolution Apex and Revolution CT, the prescribed level of ASiR-V in the primary reconstruction affects the tube output. For the same Noise Index, increased ASiR-V levels tend to reduce tube output, while reduced ASiR-V levels increase tube output
- For the same prescribed Noise Index, a smaller prescribed Slice Thickness in the primary reconstruction increases tube output
- In general, in GE AEC features across CT products, the reconstruction kernel employed in the primary image reconstruction does not affect the tube output.
- Further details are available in the technical documents that accompany the CT scanner

Advanced AEC Features Outline

- AEC in cardiac exams
- Unusual attenuation profiles
  - Head/Neck exams (strategy to handle abrupt change of attenuation profile)
  - Extremity exams
  - Neonates and very small children
  - Metal/Foreign objects within Scan FOV
  - Obese patients
- Automatic tube voltage selection
- Organ based tube current modulation

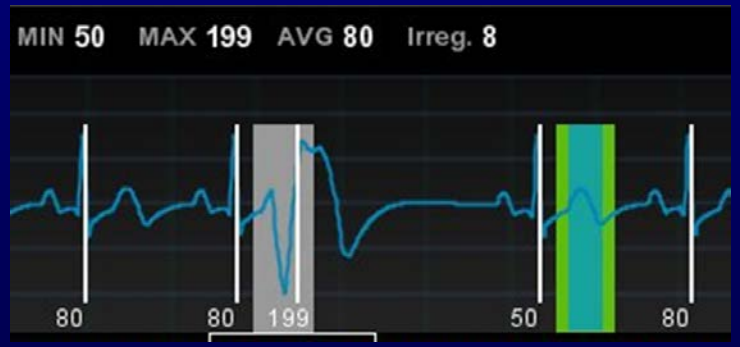
AEC in cardiac exams – GE Healthcare

- ECG-based tube current modulation is available
  - Revolution Apex, Revolution CT, Revolution CT ES offer:
    - Cardiac Axial is both prospectively-gated and has ECG-based tube current modulation
  - Other GE CT Systems offers:
    - SnapShot Pulse is only prospectively-gated with no additional ECG-based mA modulation
    - SnapShot Helical – Segment, Burst, Burst Plus – are retrospectively gated with ECG-based tube current modulation
- When ECG-based tube current modulation is activated:
  - there is simultaneous Longitudinal (z) tube current modulation per scan location for Cardiac Axial
  - there is simultaneous Angular (x-y) tube current modulation*

    * There is angular-dependent tube current modulation relative to view weighting for Cardiac Axial but not for retrospectively gated helical or SnapShot Pulse scan modes.

AEC in cardiac exams – GE Healthcare

- In Prospective Triggering Mode with table movement,
  - there is an option for tube current modulation at selected cardiac phase range for Cardiac Axial but not for SnapShot Pulse
  - there is Adaptive triggering to handle irregular heart beat.



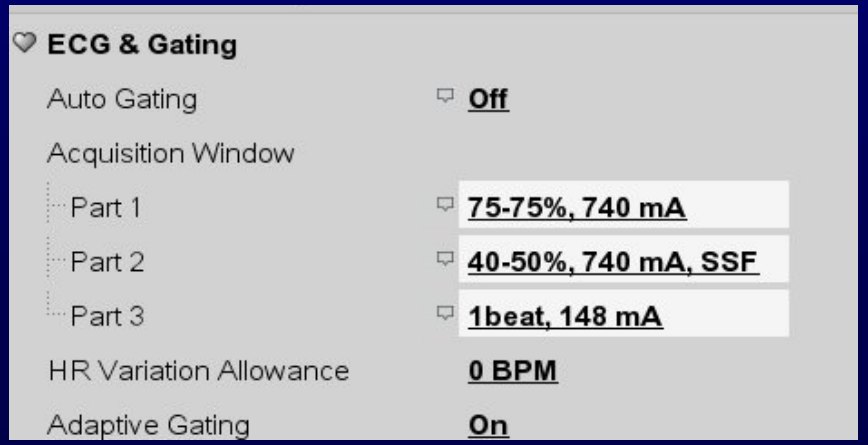
Smart Arrhythmia Management for Cardiac Axial scan mode on Revolution Apex, Revolution CT and Revolution CT ES allows for intelligent re-scan when irregular heart beats occur during the scan.

AEC in cardiac exams – GE Healthcare

- In Retrospective Gating Mode with table movement,
  - there is option for tube current modulation at selected cardiac phase range
  - the reduction of tube current is freely selected down to 20% of the max tube current.

AEC in cardiac exams – GE Healthcare

- In cardiac acquisition without table movement (i.e. using wide beam collimation),
  - within one heart beat (R-R interval), there is ECG based tube current modulation at selected phase range – Cardiac Axial allows the user to separately prescribe up to 3 target phase windows at different tube current levels (e.g. diastole at full mA, systole at full mA, and functional data at 10% of peak mA)
  - at multiple heart beats (R-R interval), there is ECG based tube current modulation at selected phase range – Cardiac Axial



Unusual attenuation profiles – GE Healthcare

- For head/neck exams, there is no specific recommendation for scanning craniocaudal or caudocranial for best AEC dose modulation

- To achieve ideal image quality/dose performance, there is not dedicated AEC parameter settings for head/neck exams.

Unusual attenuation profiles

- The following are clinical scenarios where achieving desired image quality/dose performance can be challenging with the use of AEC:
  - Scanning neonates and very small children
    - Proper centering of patient is especially important
    - Use of GE Reference Pediatric Protocols is recommended
    - Use of Auto Prescription or kV Assist is recommended to reduce dose and optimize image quality
  - There are Metal/Foreign objects within scan FOV
    - Use of higher kV may be appropriate if a significant amount of metal is present (e.g., hip implants)
    - Use of GSI MAR or Smart MAR is recommended to reduce metal artifacts in the image
  - Extremity exams:
    - Lower extremity
      - No specific feature / recommendation
    - Upper extremity with arm(s) raised up above the shoulder
      - No specific feature / recommendation
    - Upper extremity with arms(s) kept down aside the torso
      - No specific feature / recommendation

Unusual attenuation profiles – GE Healthcare

- For scans where the tube power limitations are reached using AEC, automatic adjustment of the scanning parameters is not done, but tube optimization recommendations are presented to the user for easy selection.

Automatic Tube voltage selection – GE Healthcare

- Automatic tube voltage selection based on the CT localizer scan(s) is available
  - Revolution Apex, Revolution CT with Apex edition
  - Revolution CT, Revolution CT ES
  - Revolution Ascend
  - Revolution Frontier
  - Revolution HD
- kV Assist
  - Automatic tube voltage selection algorithm is **dependent** on whether contrast media is used for the exam as applicable to clinical task.
- Auto Prescription
  - Automatic tube voltage selection algorithm is **not dependent** on whether contrast media is used for the exam as applicable to clinical task.
    - If contrast media is present, Noise Index will automatically adjust based on the chosen kV from the Auto Prescription Profile

Automatic Tube voltage selection – GE Healthcare

- Please list the parameters that specifically control the automatic tube voltage selection for this manufacturer. If applicable, please provide screenshot(s) of user interface.
  - kV Assist
    - Clinical Task Setting
    - Min / Max allowed kV
    - Baseline kV
    - Baseline NI (Smart mA)
    - Baseline mA (Manual mA)
  - Auto Prescription (kV Assist 2.0 in earlier software versions)
    - kV selected from the Auto Prescription Profile based on the Patient Size

Automatic Tube voltage selection – GE Healthcare

- The tube voltage is automatically selected based on the patient attenuation profile and exam type using the following principle
  - kV Assist
    - Lowest radiation dose for a specified contrast to noise ratio
  - Auto Prescription (kV Assist 2.0 in earlier software versions)
    - kV selected from the Auto Prescription Profile based on the Patient Size
    - Noise Index adjusted based on Clinical Task setting to maintain contrast to noise ratio
    - See User Manual and Auto Prescription White Paper for more details

Automatic Tube voltage selection – GE Healthcare

- The user is allowed to disable specific tube voltages for each exam using automatic tube voltage selection

Organ based tube current modulation – GE Healthcare

- Organ-based tube current modulation is available on all GE CT products
- The change in tube output (i.e. effective mAs) for projections over the organ of interest is 30 – 42%
- There is not compensation in tube output for projections outside the "organ of interest" range.

Organ based tube current modulation – GE Healthcare

- If organ-based modulation is activated for a CT scan, the total tube output (mAs) is lower than without organ-based modulation with other scanning conditions kept the same.

- When organ-based modulation is enabled, there is not restriction on other scanning techniques (i.e. rotation time, pitch).

- Organ-based modulation is available for all exam types except ECG gated acquisitions

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