The most powerful diagnostic image processing software from Carestream Health

DIRECTVIEW EVP Plus Software

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Summary

Acquiring radiographic images by means of either Computed Radiography (CR) or Digital Radiography (DR) enables image processing algorithms to exploit the full dynamic range of the original digital exposure data. Carestream Health has developed its most powerful diagnostic image processing software, DIRECTVIEW EVP Plus Software, available for many of its DIRECTVIEW Systems.

In summary, EVP Plus performed exceptionally well in the following areas as compared to previously patented image processing software such as Perceptual Tone-Scale (PTS), and Enhanced Visualization Processing software (EVP):

- • Significantly preferred image rendering

- • Statistically better diagnostic quality for a broad range of exams

EVP Plus enables users to automatically render images without a priori knowledge of exam or body-part. In particular, multiple exposures (several images acquired on the same cassette) can be readily accommodated and processed independently. Workflow improvements can also be expected because of these new features. Ease-of- use and exam independency with intuitive controls marks this software as an upcoming in diagnostic image processing.

The Well Known Problem

X-rays are produced by the tube head consisting of a rotating tungsten anode, a filament emitting heat electrons, and an electrostatic cup focusing the heat electrons onto the anode to an area called the focal spot. X-rays are produced by the interaction of the heat electrons with the base material, tungsten, at the location of the focal spot. In order to control the x-ray beam appropriately such that only x-rays within a restricted area are used for imaging the patient anatomy, beam limiting devices are placed at the exit of the tube head. Beam limiting devices are called collimators and are usually composed of at least four adjustable lead blades located in the same plane forming a rectangular region of interest. Opposite blades are parallel to each other. This collimated region of interest can now define the body part to be radiographed. X-rays then traverse the body part within this restricted area defined by the collimator blades, to reach the imaging detector.

The area of the image from the edge of the collimator blades to the outer edge of the available image field does not contribute useful information to the image formation process. Detection of the collimator edge is therefore important in order to select and properly render the useable image area. Factors that can affect proper detection is collimator blade design, scatter radiation due to patient anatomy, and patient positioning within the image field.

Previous image processing such as PTS and EVP required three parameters, in three separate steps, to be specified for image viewing. It was necessary to designate the body part being imaged in order for the image processing to render the optimal image quality according to the specific anatomical region image parameters (IP). Image processing was also dependent on an array of multi-variate parameters composed of dependent and independent image quality variables. In modifying one parameter, other dependent variables were likely changed, making the selection of suitable image processing parameters a long and complex task.

Furthermore, the designation of the body part for the appropriate image rendering is a multi-step process that can take valuable time especially with trauma cases requiring immediate imaging. Keystroke errors can be made with the consequence of having to enter a few additional keystrokes impeding flow within the radiology department.

EVP Plus was developed by Carestream Health to address these issues. Developed for its family of DirectView digital and computed radiography systems, EVP Plus offers image rendering without requiring a priori knowledge of anatomical body part within a well-defined collimated boundary.

EVP Plus Image Processing as the Solution

DIRECTVIEW EVP Plus Software simplifies workflow, provides easy-to-use controls and processes images composed of several views obtained from one cassette. Each image within the image field is processed separately to obtain the highest image quality for each. In addition, EVP Plus can present a rendered image without knowing a priori the body part being imaged.

The EVP Plus imaging chain begins with the image acquisition from either DIRECTVIEW CR or DR devices **(Figure 1)**. These images are subsequently segmented for the purpose of defining the relevant image anatomy and exposure fields. Unique rendering parameters are generated for each image, including each image in a multiple exposed field.

The process of rendering parameters is accomplished by extracting histogram features from the image or sub-image and applying an appropriate rendering prediction model which yields the rendering parameters. The image is decomposed into appropriate multiple frequency bands and the frequency-based rendering parameters are applied as gain factors. If noise suppression is required, the highest frequency band is adjusted according to appropriate exam dependent gain controls. The final image is reconstructed by recombining all frequency bands and applying the tone scale. Lastly, the black surround mask is applied.

EVP Plus also automatically identifies multiple radiation fields in an image and has the capability to apply a mask around each field. Each field is processed and rendered as a unique image.

The role of segmentation is to identify the exposure field in the image and define the relevant anatomy that will serve as input into the rendering process. Through the process of defining the collimator blades, the segmentation process is able to exclude the low-signal or foreground collimator blades that contain no useful diagnostic information. After defining the exposure fields, the segmentation processing finds regions of direct exposure – where x-ray photons are absorbed without attenuation by the imaging receptor. This information, together with the foreground information, enables the processing to focus on patient anatomy only. The final rendering optimally uses the full dynamic range of the output display, whether hard or soft copy, in a way that maximizes the information presented in the image while not using any output dynamic range on irrelevant image regions such as foreground and regions of direct exposure.
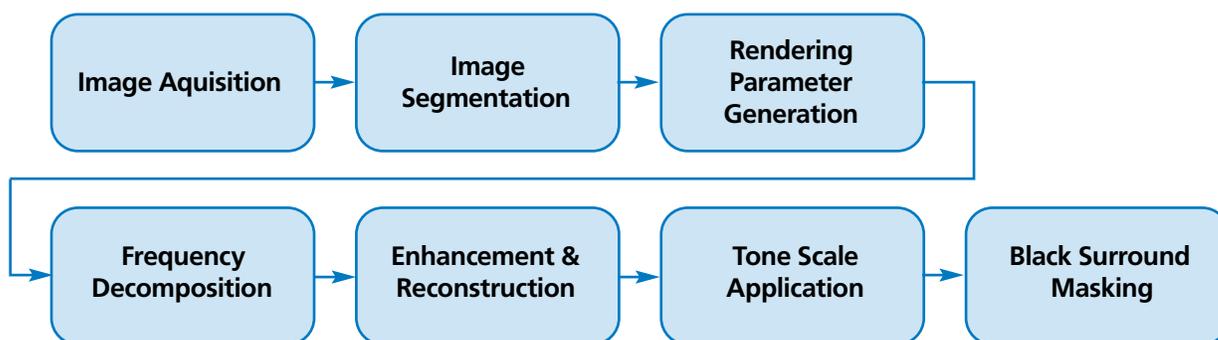
Figure 1 EVP Plus image processing chain

Clinical Evaluation of EVP Plus

In a controlled clinical study, five board-certified radiologists and one senior resident independently rated 152 image pairs composed of CR and DR images with and without EVP Plus, for a total of 1824 images scored. Sample images were selected from among 15 principle examination types **(Table 1)**. Examinations of the type 'Upper Extremities', 'Lower Extremities' or 'Skull' included specific body parts such as fibula, femur, tibia, humerus or nasal bones, as an example.

Images were viewed on dual-head NDS Axis III 3 MP monochrome diagnostic quality flat panel displays. The displays were calibrated according to the gray scale display function (GSDF) specification of the DICOM standard. Flat panel displays were located in a low-ambient reading room replicating normal diagnostic reading conditions. Each observer was provided with background information regarding the purpose of the study, the significance of the rating scales, and sufficient software application training. The evaluation software enabled the radiologist to zoom, pan and simultaneously display image pairs for direct comparison.

The evaluation software displayed the 'A' image on the left flat panel display and the 'B' image on the right flat panel display. The radiologists were then asked to select a diagnostic quality rating for the 'A' image and then for the 'B' image using a 9-point diagnostic quality scale as shown in **Table 2**. The scale captures the overall diagnostic quality of the displayed image pair such that differences in diagnostic quality can be measured and compared meaningfully.

Once the diagnostic image quality ratings were completed, a 9-point preference rating scale was utilized **(Table 3)** which measured the preference of image 'B' relative to image 'A'. A score of 0 indicated there was no preference between the 'A' and 'B' image. This scale quantifies the readers' preference, which is a particularly useful quantity when diagnosis might not be obviously impacted.

Table 1 The 15 principle examination types selected for this study.

Abdomen	Chest	Cervical Spine
Elbow	Knee	Hip/Pelvis
Pediatric Chest	Pediatric Abdomen	Portable Chest
Lumbar Spine	Lower Extremities	Skull
Shoulder	Thoracic Spine	Upper Extremities

Table 2 Diagnostic image quality scale

9	Very Satisfied	Optimal for evaluating the appropriate category of information
8		
7	Satisfied	Acceptable for interpretation; no loss of information
6		
5	Niether Satisfied or Dissatisfied	Sub-optimal image, bordering on loss of information, subtle abnormalities could be lost
4		
3	Dissatisfied	Poor image that impairs interpretation, important information could be lost, the interpreter would consider reprocessing
2		
1	Very Dissatisfied	Inadequate for diagnosis, definite loss of information, the image should be reprocessed

Table 3 Preference rating scale

4	'A' image Markedly better	Diagnosis likely altered
3	'A' image Clearly better	Diagnosis might be altered
2	'A' image Somewhat better	Diagnosis should be the same
1	'A' image Slightly better	Diagnosis will be the same
0	NO Difference	
-1	'A' image Slightly worse	Diagnosis will be the same
-2	'A' image Somewhat worse	Diagnosis should be the same
-3	'A' image Clearly worse	Diagnosis might be altered
-4	'A' image Markedly worse	Diagnosis likely altered

The Results

A rating of 7, 8, or 9 on the 9-point diagnostic image quality scale indicated that a participating radiologist considered an image 'acceptable for interpretation' with 'no loss of information' or 'optimal' for clinical evaluation. On this 9-point scale, the percent rated 7 or better was more than 67% for the EVP Plus images compared to 49% for the Control images. The median rating for the EVP Plus and Control images was 7, indicating that both were 'acceptable for interpretation' with 'no loss of information' as shown in **Figure 2**.

CR and DR Diagnostic Quality Scores
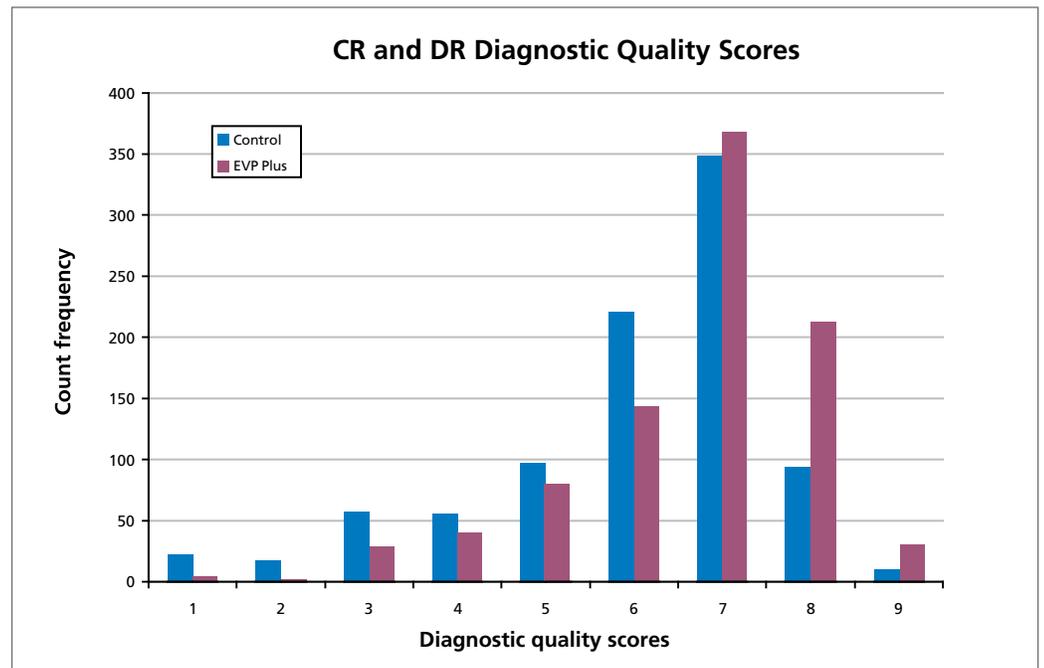
Figure 2 Digital radiographic images with EVP Plus compared to Control images. The mean is 7 indicating that both were 'acceptable for interpretation' with 'no loss of information'.

A rating of 1, 2, or 3 on the 9-point diagnostic image quality scale indicated that a participating radiologist considered an image so 'poor' that it 'impairs interpretation' and that 'important information could be lost'. On the 9-point scale, the percent rated 3 or less was 4% for EVP Plus images and more than 10% for the Control images, a clear indication that EVP Plus can render superior diagnostic quality images.

Another way to view the data is to look at the differences in diagnostic quality ratings for each image pair, where 0 indicates no difference between the Control and EVP Plus images. A negative rating on the preference scale indicated a lower preference for the Control image and a positive value indicated a preference for the EVP Plus images. In this study, the EVP Plus images were preferred in about 52% (p<0.0001) of the cases **(Figure 3)**. Generally consistent results were obtained across all examination types studied.
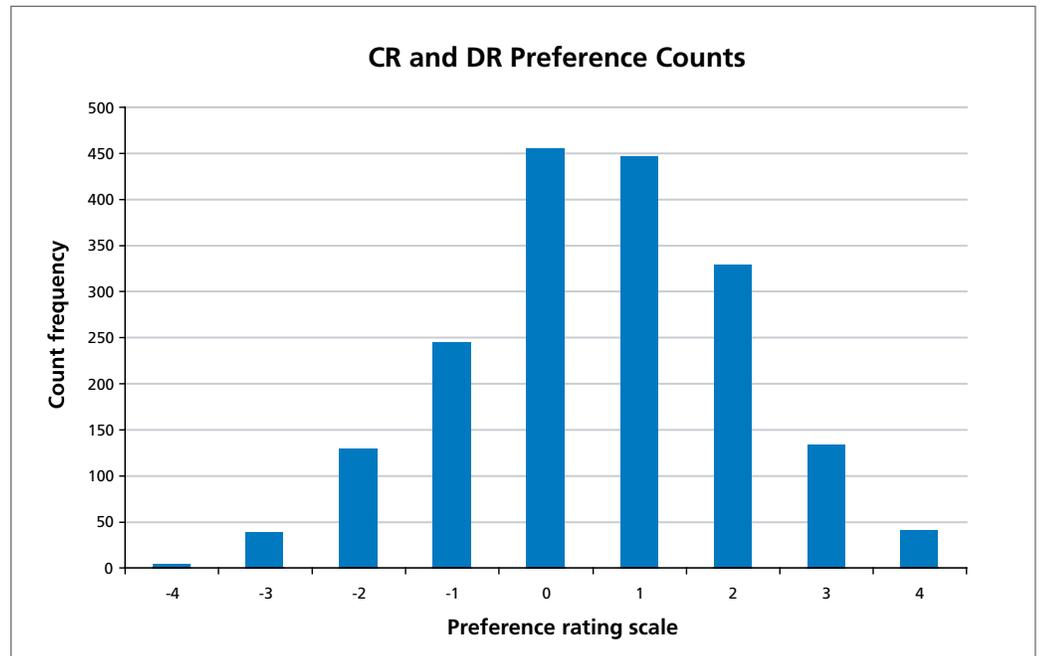
Figure 3 Generally consistent results were obtained across all examination types studied.

The full dataset was comprised of both examindependent and exam-dependent images. Examindependent images were images rendered with no body part pre-selected. Exam-dependent images were images rendered with the three-step body part selection process. Both the Control images and the EVP Plus images could be either acquired with or without the body part selection process. Selecting only the exam-independent images and their respective preference and image quality scores from the full dataset formed a specific subset. **Figure 4** represents a histogram of the digital radiographic images with the corresponding diagnostic image quality scale ratings.
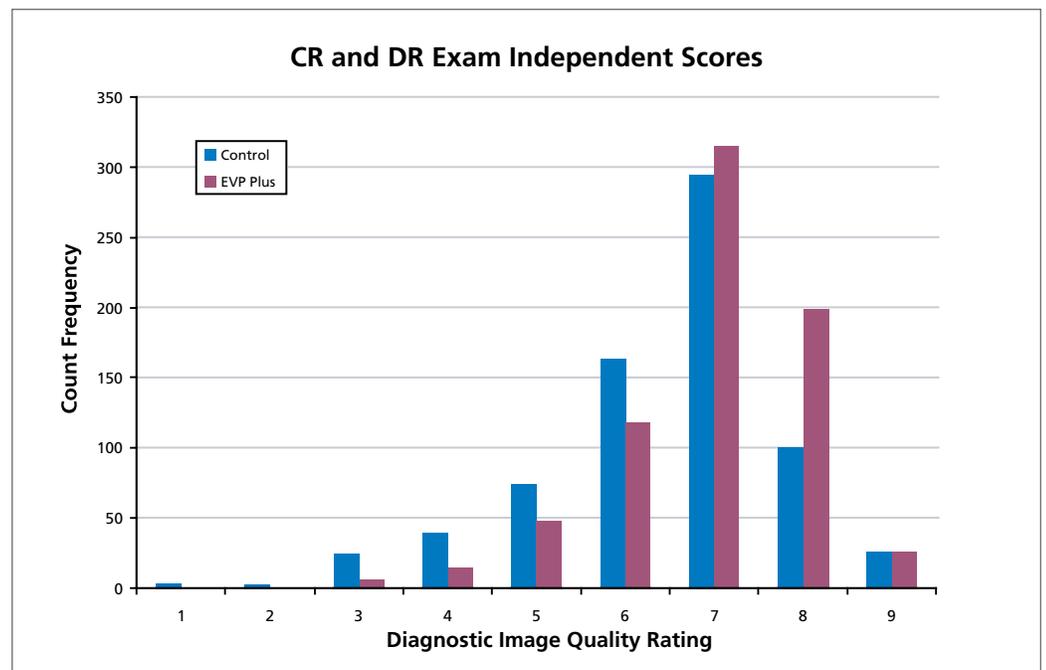
Figure 4 Subset containing only the exam-independent images from both the CR and DR systems. EVP Plus was preferred in over 74% of the cases. A rating of 7 or higher indicated a preference for EVP Plus.

A total of 726 DR and CR images were scored from this subset evaluated by 5 board-certified radiologists and 1 senior resident. The mean was 7 indicating that images were 'acceptable for interpretation' with 'no loss of information'. Image quality for EVP Plus was preferred in more than 74% of the cases (p<0.0001). Results graphed in **Figure 5** indicated that over 52% of the EVP Plus images were preferred (p<0.0001).
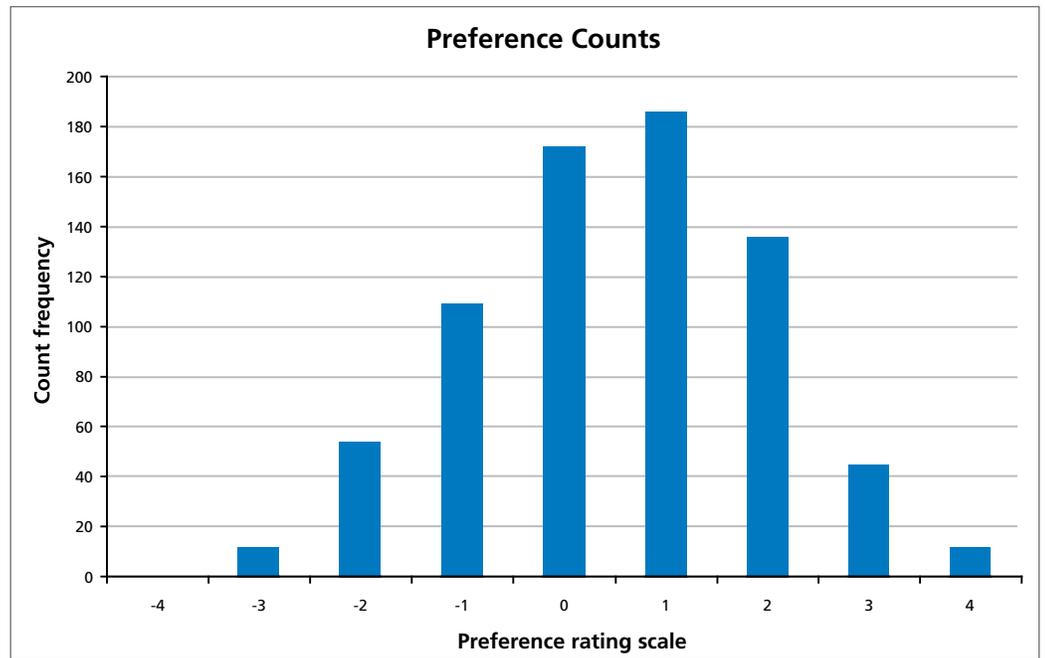
Figure 5 Preference ratings for the exam-independent images. Ratings equal to or greater than 1 indicated EVP Plus images were preferred over the Control images (p<0.0001).

Conclusion

Five board certified radiologists and one senior resident rated images processed by EVP Plus clearly superior in terms of diagnostic preference quality compared to images processed by the current base software available for CR and DR products. The results were largely independent of examination type.

While demonstrating the diagnostic preference quality of EVP Plus images is not equivalent to demonstrating that EVP Plus images improve diagnostic accuracy or radiologist productivity, these preliminary results strongly suggest the likelihood of these desired outcomes.

In summary, the commercial availability of the DIRECTVIEW EVP Plus software algorithm represents another significant step towards optimally exploiting the full range of the exposure data captured by the DIRECTVIEW digital capturing systems.

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