UpRight: A Radiographic Marker That Displays Upright Angle on Portable Chest and Abdominal Radiographs

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Chest x-ray (CXR) examinations are performed daily on most intensive care unit patients. Portable CXR or abdomen examinations often are obtained in patients' hospital beds when they are too sick to transport to the radiology department for an upright posteroanterior and lateral CXR or upright abdomen imaging. Routine and nonroutine indications for portable CXR have been described in the literature.[1] Patients with pleural effusions, for example, benefit from having upright images taken because the fluid settles with gravity (see **Figure 1**). Pleural effusions are common in critically ill patients and are optimally evaluated on upright CXR.[2,3] However, knowing the degree of angle of each projection would help evaluate serious conditions across serial CXRs. Portable radiography of the chest often is inconsistent and inadequate because of lack of positioning indicators.[4,5]

Conversely, any trapped air rises and when together in the same cavity (eg, in a hydropneumothorax, abscess, or empyema), an air-fluid level or free abdominal air can best be detected on upright examination. Most portable abdominal radiographs are supine because the patient is nonambulatory in most cases. Decubitus projections often are necessary to rule out free air. Basically, positioning of the patient, plate, bed, and tube relative to gravity is paramount, yet there has not been a method to capture this phenomenon until now.

The portable CXR usually is not fully upright because the x-ray tube would have to be practically in

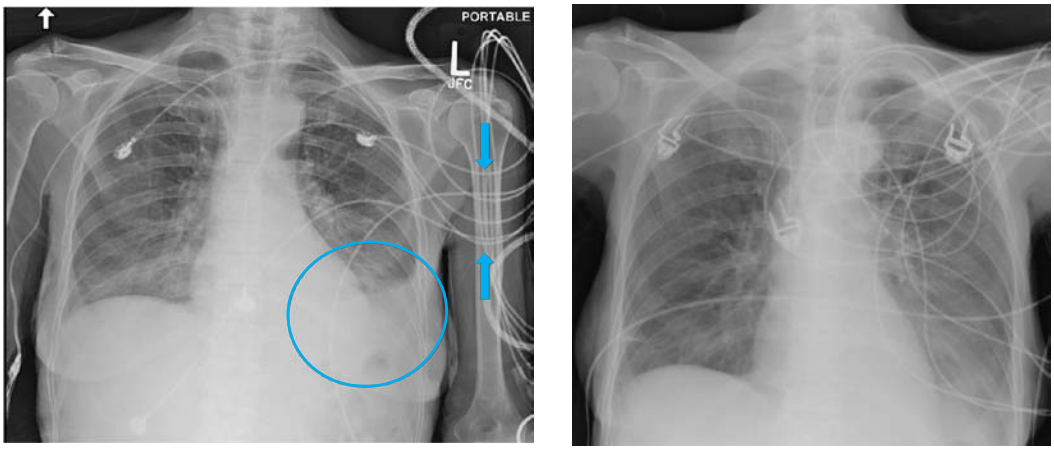


Figure 1. *A. An upright chest radiograph demonstrating a left plural effusion. The up arrow indicates an upright projection, but there is no rule how upright a projection has to be to include the arrow among technologists. B. More supine image that shows the effusion distributed as a hazy, ill-defined opacity over the lower left hemithorax. Without knowing the degree of angulation, comparison of pleural effusion or differentiating from a consolidation is often very difficult.*

the patient's lap to obtain an erect orientation similar to that obtained in the department. Many portable CXRs are obtained at 45° or less, often because of patient condition or the projection the technologist performs. To achieve optimal exam quality, technologists are taught to attempt the most upright projection, balanced with patient condition and ability to achieve this often impossible task. If images are obtained at similar angles each day, even if not fully upright, it would allow accurate comparisons and assessment of change.

Radiologists often disclaim findings that could be masked or mimicked with overlying densities resulting from lack of upright indication. A radiologist cannot rule out free intraperitoneal air (air noted under the diaphragm), for example, without knowing the projection was nearly erect, nor can fluid levels such as hydropneumothorax be assessed consistently over time with variable positioning without indication of position. This compromised quality has been recognized for years; however, little has been done to provide a reliable indicator to optimize comparison of serial exams.[6] The need for therapeutic interventions such as chest tubes or thoracentesis are difficult to determine or evaluate without consistent upright projections; however, we believe that knowing the degree of inclination across serial exams will help negate the need to bring patients to the department with numerous chest drains, IV lines, and other support devices.[7]

There are many examples of clinicians ordering a computed tomography image to differentiate effusion vs consolidation (eg, representing pneumonia) or to simply compare effusions because upright angulation is rarely truly accomplished, or known when it is upright. This results in about 50 to 100 times the amount of radiation exposure, greater expense, and unnecessary patient transport to the radiology department.

In this pilot study, the UpRight prototype device appears to be a more objective and quantitative indicator that demonstrates this angulation while providing an incentive for the technologist to obtain the most upright projection possible. This would be useful for quality assurance over time with individual technologists, especially in hospitals with radiologic technology training programs.

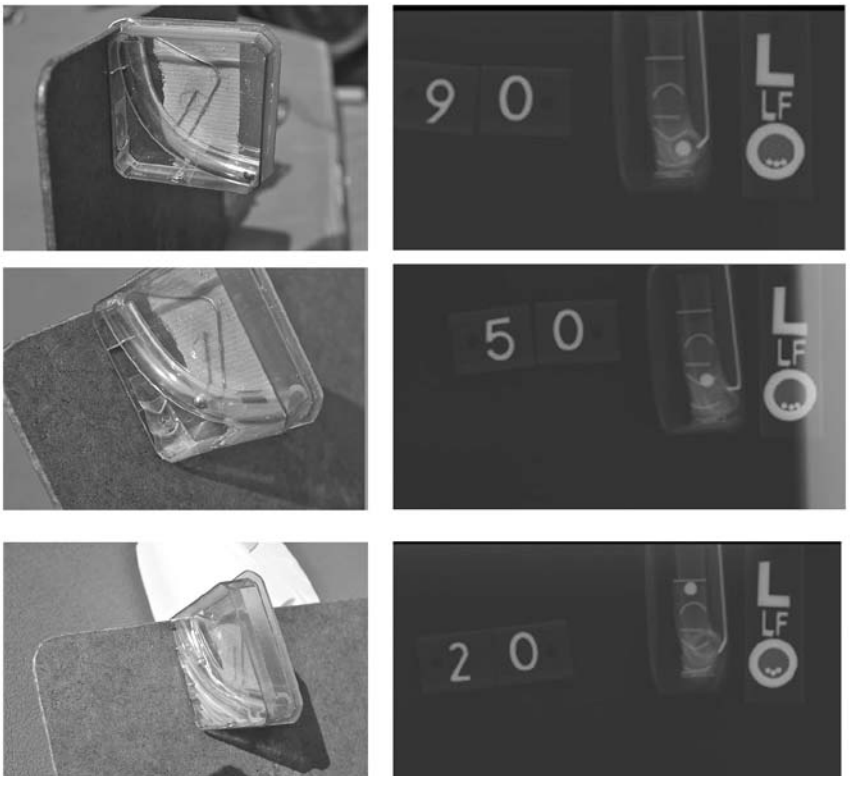


Figure 2. *The second prototype UpRight construction and 3 example angles of 90°, 50°, and 20° on a clipboard.*

Methods

We assessed the ability of 2 prototype radiopaque inclinometers to indicate approximate angle of patient inclination ranging from supine to erect, in vitro and in vivo. We also compared the more comprehensive scaled devices with an existing commercial marker consisting of a small ball bearing in a bubble on a chest phantom in various positions.

Prototype Construction

This article's lead author invented the UpRight device. An initial prototype was built and tested to help refine a second, smaller device and was made of a curved plastic tube, a small ball bearing, and metallic clips.

The clear plastic cylinder allows the ball to roll freely, resulting in visualization that verifies position. The sides are flat to allow consistent flush contact with the cassette. The metal clips are cut and taped to the cylinder in 10° increments (0°-90°) to differentiate inclination angles. A serpentine-shaped clip suspended the device on a cassette (see **Figure 2**).

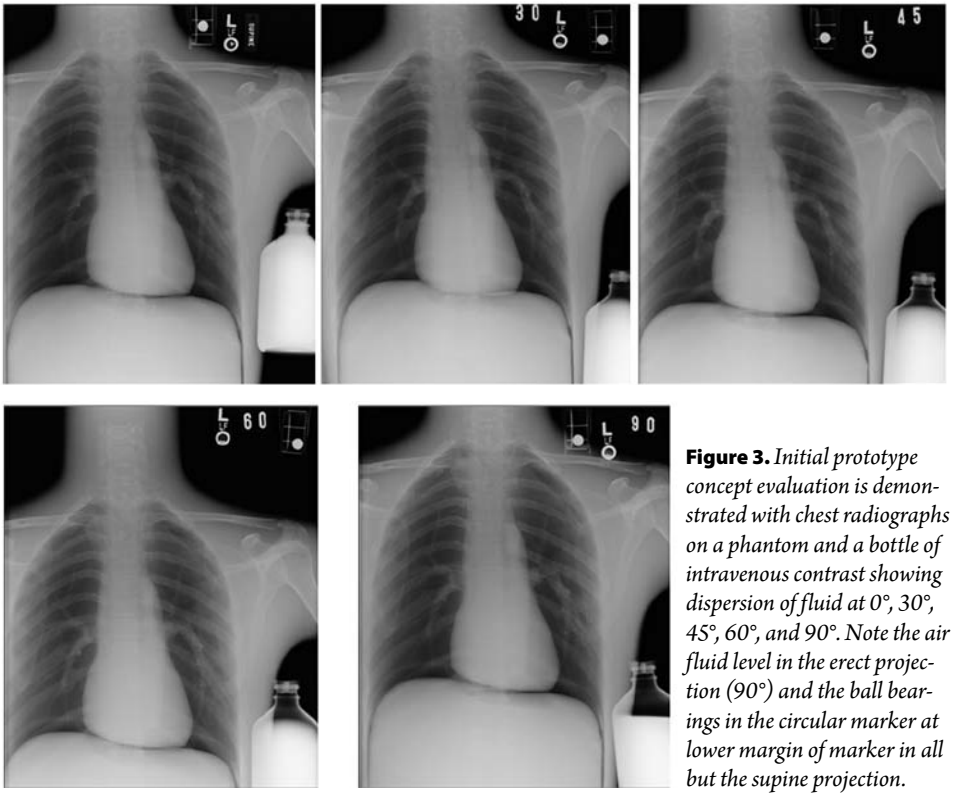


Figure 3. *Initial prototype concept evaluation is demonstrated with chest radiographs on a phantom and a bottle of intravenous contrast showing dispersion of fluid at 0°, 30°, 45°, 60°, and 90°. Note the air fluid level in the erect projection (90°) and the ball bearings in the circular marker at lower margin of marker in all but the supine projection.*

Laboratory Setting

The researchers assessed the UpRight at 10° increments and compared the device to a commercially available marker (ie, 3 small lead balls in a bubble) with a chest phantom and a bottle of IV contrast. Three independent reviewers were provided a guideline with images of the device from radiographs taken at various angles. They reviewed 10 radiographs and recorded at what angle they felt the projection was taken based on the scale provided.

Figure 3 demonstrates example major angles showing the prototype tested along with the positions and radiographs.

Clinical Setting

The UpRight device was placed on 27 consecutive portable CXR images by 1 of 2 technologists. A radiologist was provided a visual scale consisting of radiographs of the UpRight at each of the 10° increments and recorded what they believed the inclination to be on the CXRs by visually comparing them to the reference device images.

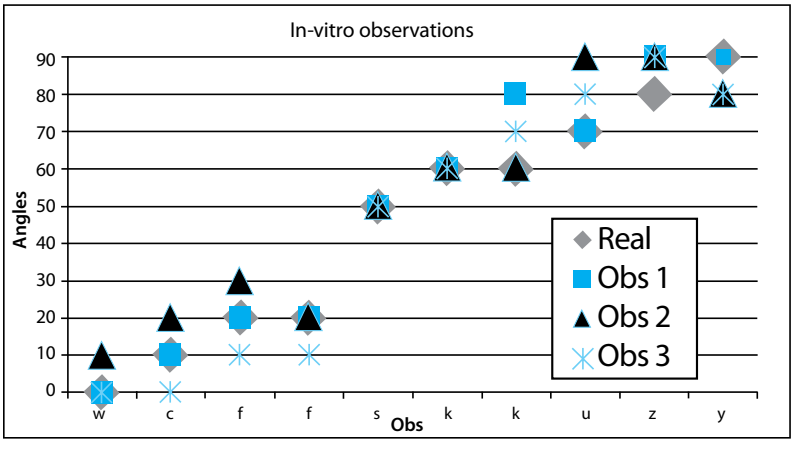


Figure 4. *Summary of actual phantom inclination angles and observer estimates. Note that there were few instances of discordance (beyond 10°) of observer-estimated angle and actual angle. An example is 70° where observer 2 selected 90° and observer 3 selected 80°. Because the 10 chosen angles were randomly selected, 2 were selected twice (20° and 90°), leaving 2 unevaluated (30° and 40°).*

Results

Laboratory Setting

The UpRight device estimated the inclination angle of the cassette and phantom within 10° in 28 of the 30 observations. The 2 observations outside this range were both within 20° (see **Figure 4**). The current commercially available marker was only able to discern supine vs not supine (20° and higher).

Clinical Setting

The radiologist estimates of the degree of inclination were within 25° on all patients. **Figure 5** demonstrates differences between the actual and estimated angles. Of note, the radiologist consistently overestimated the angle.

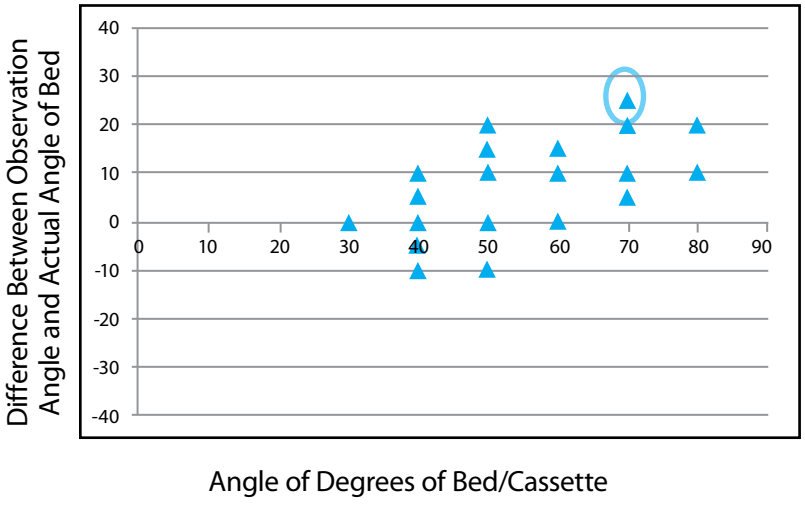


Figure 5. *Summary of actual inclination angles and radiologist estimates on 27 patients. The largest error was 25° (circled); the radiologist estimated the angle as 45° when the actual angle was 70°.*

Discussion

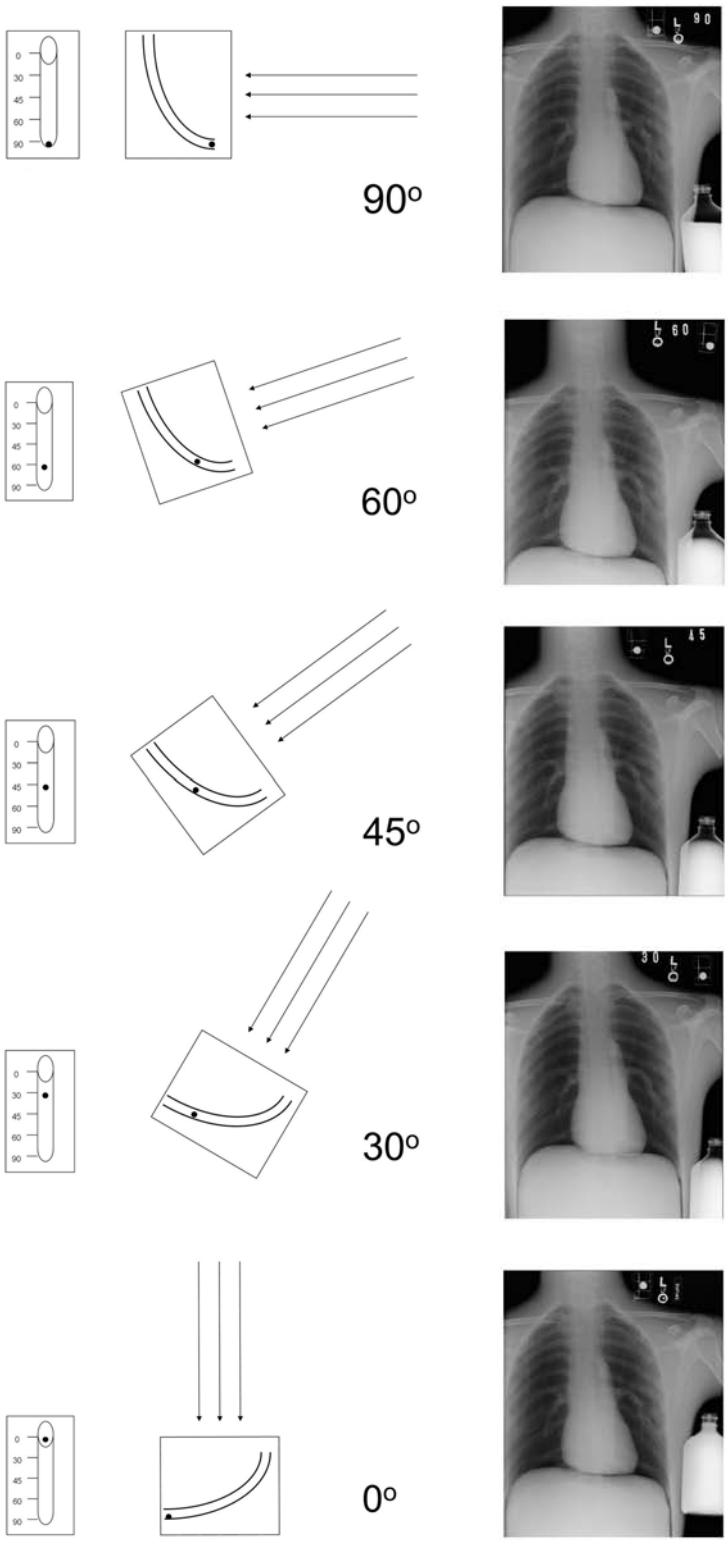
The UpRight prototype indicated the degree of cassette angulations much more accurately than the marker that is currently available. The laboratory testing of the UpRight demonstrated that the angle of inclination is successfully quantified within 20° in simulated portable CXRs. On actual portable CXR images, a radiologist estimated the angle of inclination within 25°. The radiologist consistently overestimated the angle of inclination, which the researchers thought to be due to the difference in beam divergence on the laboratory scale. In the laboratory, beam divergence was accomplished on a 14 × 17-inch cassette lengthwise, but the actual portable CXRs were performed on a 14 × 17-inch cassette crosswise.

The UpRight is a simple radiopaque ball bearing that settles in a curved tube because of gravity. The ball is seen relative to various radiopaque metal markers indicating angle of inclination. The advantage over prior devices is that the device quantifies the angle of inclination (see **Figure 6**); other devices only indicate supine or not supine.

When upright abdominal examinations are attempted, the UpRight radiographic marker may provide the radiologist with evidence of degree of inclination and help determine whether air can be ruled out — a common indication for obtaining abdominal exams. This method and device also can be used for portable and interdepartmental abdominal exams. When in the department, the technologist often uses the table to achieve a more upright angle, and the UpRight can help the radiologist determine if free air is a possible finding.

More precise quantification of pleural effusions may be possible with the UpRight device, especially when comparing CXR images over time, assessment of air-fluid levels in abscesses or empyemas, and ruling out subdiaphragmatic free air. Effusions can mask consolidations (eg, radiographic indicators of pneumonia). However, UpRight may help determine if occult pneumonia — a cause of increased morbidity and mortality — is developing by allowing differentiation of effusion or consolidation with known inclinations. Effusions often indicate severity of patient condition and, at times, require drainage. Increasing effusion over time is an indicator of need for immediate thoracentesis, and with further testing, can more effectively be assessed with the device. Widespread use of UpRight may allow for improved diagnosis and comparison of effusions.

The UpRight should help technologists and radiologic technology students improve their performance over time as they try to achieve the most upright



projections possible. Educational program faculty and clinical instructors can establish trends among students over time and compare to other technologists for continual quality improvement.

Future Considerations

Two pocket-sized UpRight devices soon will be commercially available (World Concepts Inc, Kennedyville, Maryland, and APS Global, Silver Spring, Maryland) that are more streamlined, pocket-sized, and include a left or right marker (see **Figure 7**). Early production units will display degree markings at 0°, 30°, 45°, 60°, and 90° (see **Figures 8** and **9**). This should support that further accuracy is not practical at this time, while providing more quantitative information than currently provided (either supine or erect). More research is needed to establish clinical use. World Concepts Inc and APS Global are collaborating to produce and distribute the most efficient and compact UpRight with initial applications of the first prototypes. These should be on the market soon through both companies.

Microelectronic versions using microelectromechanical system accelerometers will allow more precise inclination of the cassette and tube. This information can be sent to the DICOM data of the image. However, because these may be prohibitively expensive at first, a simple, affordable, and immediate solution such as UpRight is necessary.

The initial prototype and this pilot study have several limitations. In the clinical setting, variable positioning allowed for

Figure 6. *Design and implementation of prototype UpRight evaluated in this study. The arrows indicate the direction of the x-rays and the device is seen from the side of the cassette.*

Figure 7. *Photos of recently manufactured prototype UpRight markers that will be available commercially soon. The image on the right (A) shows the ball just under 45°. The marker on the left (B) has a radiopaque pendulum that indicates angle and has yet to be tested.*

a larger margin of error. In addition, the prototype has reference markers, but no actual indications in degrees. Also, only 1 radiologist estimated angle of inclination. Last, although angle of inclination can be estimated within 30°, there is not yet proof that this will help in patient care.

These issues will be further studied a multi-institutional study with the latest production UpRight marker. Angles recorded by the technologist were determined from the bed angle indicator, which may not always indicate the plane of the plate or patient. An external angle device demonstrated that the angle was often off by approximately 10°. Although the researchers evaluated in 10° increments, 30° increments may be more realistic and should be accurate for most applications.

Conclusion

The UpRight device reflects the angle of inclination of cassette in portable radiography more precisely than positional markers currently available commercially. The device allows radiologists to more effectively compare serial CXRs, thereby increasing the ability to properly assess and communicate certain diagnostic findings on portable chest and abdominal examinations by knowing the degree of inclination. Using this device, radiologic technology students can improve their positioning by recording and comparing frequency and degree of upright projections. Following further evaluation and actual use, this device may decrease the need for obtaining computed tomography scans, thus reducing unnecessary radiation and additional expenses.

Les Folio, DO, MPH, BSRT, is a radiologist in body imaging and lead radiologist for computed tomography at the Clinical Center at the National Institutes of Health (NIH) in Bethesda, Maryland. He is also an adjunct clinical professor at George Washington University Hospital. Dr Folio invented the UpRight years ago and built the

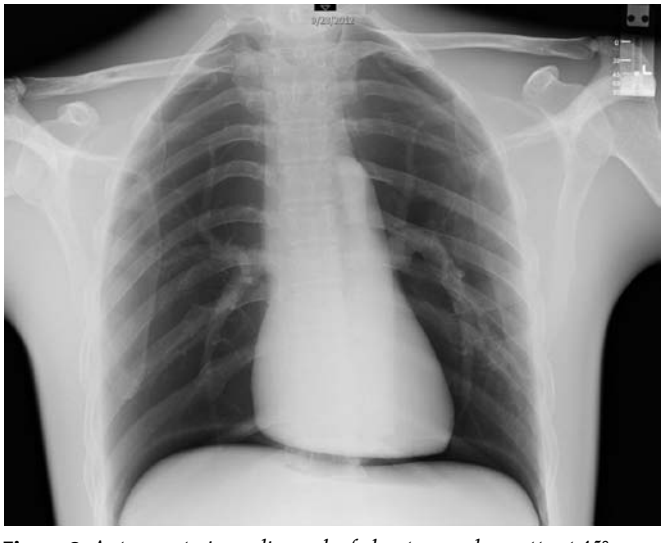


Figure 8. *Anteroposterior radiograph of phantom and cassette at 45° position demonstrating UpRight with ball aligned with 45° marker.*

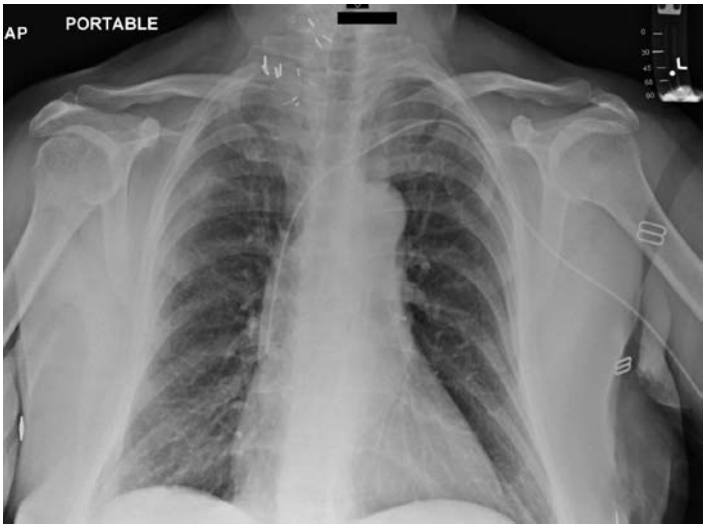


Figure 9. *Radiograph of patient with UpRight markers showing approximately 50° (between the 45° and 60° indicators) inclination.*

prototype tested and evaluated in this paper. He would like to thank his son, Lucas Folio, for helping him build the first 2 prototypes. Without his inspiration, persistence, motivation and curiosity, the UpRight would not have advanced to the current state. Dr Folio will present these findings and current research on the UpRight at the RSNA 98th Assembly and Annual Meeting November 25-30, 2012, in Chicago, Illinois.

Michael Spivey, R.T.(R), and Jennifer Chaney, R.T.(R)(M), are diagnostic technologists in the department of radiology and imaging sciences in the NIH Clinical Center. They applied the UpRight prototype marker on portable chest x-rays at various angles of inclination.

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