Instructions for the use of the Chest Reading and Recording System: 2007 Version

The Chest Radiograph

a. CRRS is designed for recording the radiographic features of a standard postero-anterior chest radiograph. Although lateral chest radiographs are useful for diagnosis, they are not used in surveys because their quality is more difficult to assure in the field setting, and they are more difficult to read, and add relatively little additional information at increased cost.
A successful radiographic survey requires the following:

- Chest radiographs of suitable quality performed on equipment that is suited to this task. A description of the technical requirements and required quality of the radiographs is provided below.
- Two accredited CRRS readers with access to a reading environment, and the necessary assistance to perform reading as described below. They should do so independently of one another.

b. The current version of CRRS has not been validated for reporting digitally- acquired radiographs. Digital images require standardization before they can be used in surveys. This process is underway and will be included in a later version of the CRRS.

c. Reference radiographs, such as those used in UICC/ILO system of reporting for occupational lung disease are not used in CRRS because

- CRRS is not intended for detailed examination and quantitation of diffuse parenchymal abnormalities and their progress over time
- The grades of size and profusion of small opacities have been limited to 3 categories each, thereby eliminating the need for reference radiographs
- The cost and technical demands of producing standardized radiographs would limit accessibility and usage of CRRS for field work.

d. Readers should not refer to previous radiographs from the same patient when evaluating radiographs, as this introduces a potential bias. If several radiographs from the same subject require reporting, they should be reported blind, in random order but not sequentially in the reporting session.

Obtaining quality chest radiographs

A primary requirement for chest radiographs performed to assess the tissues of the lung (soft tissues) are different to those generally used in X-ray departments where the emphasis is on denser structures like bone, where the emphasis is on contrast and shorter exposures. While most modern equipment can provide the necessary performance for chest films, this need must be considered when equipment is acquired for chest radiology surveys, and adjustments may need to me made to satisfy specifications for chest radiology.

Specifications for equipment:

- A high output generator (capable of short exposure times)
- X-ray tube capable of 125kV or more
- For lung tissues, a focal spot size of 0.6 to 1.5mm
- A fine grid/bucky that can be focused up to 1500mm (to prevent magnification of the heart.
- Medium speed cassette/screen combination (+/- 200). A faster screen (e.g. 400) produces grainy images with excess contrast.
  A reliable well-maintained processor with regular replacement of chemicals.
- Radiographic technique for obtaining satisfactory chest radiographs:
- Patient preparation: Remove clothing, foreign objects on the chest.
- Patient instruction: how to inhale and breath-hold (arrest respiration) at full inspiration.
- Patient position: Erect; postero-anterior exposure; hands pronated and arms placed around the cassette to ensure that scapulae are not within the field of interest (lung fields); centred (not rotated); and neither lordotic (backward flexed) nor kyphotic (forward bowed).
- The SID (distance to plate) must be 1500mm.
- Collimated to ensure that the whole thorax and surrounding chest wall bony and soft tissues are included on the film.
- A Left or Right indicator must be included.
  Name (or identification number) and date must be visible on the films.

Some common problems and pitfalls in obtaining quality chest radiographs and how to address them:

- Rotation of thorax - check that head is not turned to one side.
- Film paler on one side - check for rotation of the thorax; check that beam is at right angles to grid.
- Film dark but spinal disc space visibility is correct – exposure may be too high (mAs), or screen too fast (use slower one), or lungs hyperinflated.
- Film too pale, but spinal disc space visibility is correct – exposure too low (mAs), or patient obese, or SID (distance from source to grid) is too great.
- Film to dark, and too many joint spaces visible – over-penetrated ((kV too high), or patient small.
- Film correct in lung apices , but too pale in bases – patient obese or large breasts - an additional basal view might be necessary.
- Film shows too much contrast between ribs and lung tissue, or “grainy” – a slower screen is required, or developer temperature might be too high.

- Marks, streaks or unusual shadows on the film – handling and processing might be faulty causing artifacts, or artifacts on cassette.

Certification of CRRS Readers

a. Certification of CRRS readers is provided both to recognise those who have undergone training, and as a means of assuring readers of reports and publications of the proficiency of those that have reported on the chest radiographs in surveys. Two grades of trained CRRS readers are recognised.

- An "A-grade" reader has attended a recognised 3-day CRRS training course and undergone but not passed the course evaluation, and is certified to take part in surveys involving the CRRS as one of two reporters, provided the second reader has a B grade rating.
- A "B-grade" reader has attended a recognised 3-day CRRS training course and attained the required score during formal evaluation. He/she is certified to take part in surveys using the CRRS with either an "A-" or "B-grade" reader.

An "A-grade" reader who wishes to upgrade to a "B-grade" rating, need not re-attend a CRRS course, but must take part and pass the formal evaluation at a future date.

b. In research projects and surveys, a minimum of two trained readers, of whom at least one must be a "B-grade" certified CRRS reader, should report on each radiograph.

c. In order to improve the quality and consistency of reporting and reduce interobserver error, before beginning a survey, both readers should independently read at least 50 radiographs, the majority of which contain abnormalities. Where reports differ, the readers review the radiograph together to reach a consensus view. Agreed reports on each radiograph should be retained for future reference, as a guide to differences that occur during the conduct of the study. The major categories on which concordance should be attained are

- Parenchymal abnormalities
- Pleural abnormalities
- Central abnormalities and
- Other abnormalities
- When a radiograph is considered unreadable,
- When a radiograph is normal and
- When abnormalities should be judged as consistent with TB

d. During reporting, readers must be blinded to the history and clinical features of the subject and to the report of the other reader. The radiographs should be read in random order, that is, not in serial numerical order. Where radiographs are reread, then the order of the radiographs must be changed.

e. CRRS is updated from time to time. All certified readers will be informed by email of courses, changes to the system and new versions of the CRRS as they occur. These details will also be posted on the CRRS website (www.lunginstitute.co.za)

The Report Form

a. Configuration : The form is a single page. The top of the form has positioning blocks at each corner and a unique serial number. This allows the form to be easily aligned for rapid digital scanning or facsimile capture. Each subject is identified by a 6 digit subject number.

b. Data entry : The form should be completed by hand. A black pen is advised. To enable clear data capture a cross should be made in the applicable block with bold strokes. Care should be taken to not stray out of the block especially into adjoining blocks as this may affect both data capture and where used, digital or facsimile capture.

1. Radiograph ID

a. For reasons of confidentiality the form must not contain a personal identifier such as name, date of birth or address. Each subject is assigned a unique subject number of up to 6 digits. This is placed in the section titled ' Radiograph ID'. The code linking subjects to their identity must be stored separately according to the requirements of the local ethics review board.
b. Each digit (1-9) is made recognisable for capture as a squared-off number in a grid of six dots arranged in 2 columns each containing three dots. Numbers are written as follows. 1 = join 3 left hand dots or join all three right hand dots ; 2 = join all dots starting with the top left dot and ending at the right bottom dot. 3 = join all dots starting at the top left dot to form a 3 ; 4 = join top two dots on left, middle two and all three dots on right ; 5 = join top dots, left hand upper two, middle two dots ,right lower two and bottom two dots ; 6 = join top two, left three, bottom two, right lower two and middle two ; 7 = join upper two and right hand three ; 8 = join all six dots to form the number 8 ; 9 = join top two, left hand top two, middle two and right hand 3 to write 9. For a zero join all six dots with a single continuous line.

2. Reader ID

Each reader should be assigned a reader number. The code identifying readers must be stored away from the reporting forms, according to the requirements of the local ethics review board.

3. Date of Radiograph and Date of Reading

These dates should be included on all reports and written according to the day (d) month (m) and year (m) markers. Note that a zero can be placed before a single digit date, month or year for increased reporting precision. For example ; 6 May 2008 could be written as 06 : 05 : 08

4. Radiograph Quality

The quality of the radiograph must be judged as optimal, suboptimal or unreadable. If either of the two categories optimal or suboptimal is selected, the radiograph is considered as readable. Where it is recorded as suboptimal, a reason must be provided: "Too dark/too light", "Poor position" or "Other". If the latter, a written comment should be entered into the adjacent box.

a. To be classified as **optimal** a radiograph must be

- Correctly labelled. The following must be visible:
  - an original left or right indicator
  - an identity number which serves instead of a subject name
  - a date
- Correctly positioned:
  - No rotation – an equal distance between the dorsal spinal process of the 4th thoracic vertebra and the medial end of each clavicle
  - The 4th thoracic vertebral body must overlie the suprasternal notch (between the ends of the clavicle) such that the lung above the clavicles can be viewed through at least two full intercostal spaces.
  - The arms must be inwardly rotated to ensure that the scapulae do not overlie the lung fields.
- Correctly collimated:
  - The whole thorax including the first rib, costophrenic angles and lateral ribs must be included.
  - Equal and sufficient (approximately 2 cm) soft tissues on lateral chest walls must be included.
- Correct exposure settings:
  - Relatively little contrast between lung structures (vessels and parenchyma) and ribs, all appearing as shades of white and grey
  - The outline of the whole thoracic spine must be visible, but the intervertebral discs of only the first 4 thoracic vertebrae must be clearly seen.
- Free from extraneous artifacts over the field of interest (the area described above) caused by clothing, pacemakers and other objects.
- Free of artifacts, lines and stains and other abnormalities from processing and handling.

b. A radiograph is considered **sub-optimal** if any of the above is present.

- Incorrectly positioned but not sufficient to prevent assessment of the field of interest:
  - Minimal rotation – the distance between the dorsal spinal process of the 4th thoracic vertebra and the medial end of each clavicle is up to two cm greater on one side than the other.
  - Mildly lordotic or kyphotic views -- the 3rd or the 5th thoracic vertebral body must overlie the suprasternal notch (between the ends of the clavicle)
  - A small portion of the blade of the scapula (less than two cm on either side overlies the lung field)
- Collimation not optimal:
  - The whole thorax including the first rib, costophrenic angles and lateral ribs is included, but soft tissue is cut off on one or both sides.
- Exposure settings not optimal:
  - Too much contrast between lung structures (vessels and parenchyma) and ribs resulting in loss of clarity of vascular structures and bronchial walls, but they are visible.

    - Too little contrast between lung structures (vessels and parenchyma) and ribs resulting in partial obscuring of blood vessels and bronchi, although their outline is still visible. No air bronchograms are evident.
- An extraneous artifact is present but not obscuring the field of interest (for example a small clip, or metal object)
- Free of artifacts, lines and stains and other abnormalities from processing and handling over field of interest.

c. A radiograph is reported as **unreadable** if any of the following is present.

- In-correctly positioned, preventing assessment of the field of interest:
    - Rotation – the distance between the dorsal spinal process of the 4th thoracic vertebra and the medial end of each clavicle is more than two centimetres greater on one side than the other.
    - Lordotic or kyphotic views: Two or fewer, or, 6 or more thoracic vertebral body overlie the suprasternal notch (between the ends of the clavicle.
    - A large part of the blade of the scapula (more than two centimetres on either side) overlies the lung field
- Poor collimation
    - Any portion of a rib or the costophrenic angles not included in the field.
- Exposure settings not optimal.
    - Too much contrast between lung structures (vessels and parenchyma) and ribs. Lung field appear black with loss of vascular outlines, and ribs margins very clear.
    - Too little contrast between lung structures (vessels and parenchyma) and ribs resulting in obscuring of blood vessels.
- An extraneous artifact is present over the field of interest.
- Artifacts, lines or stains from processing and handling are present over the field of interest.

5. Parenchymal abnormalities

The CRRS defines the parenchyma as the area involving the lung fields including the airways and vascular structures. Because the emphasis is on description with some anatomical definition, but not pathological descriptors, vessels are described both as masses and in the last section of the form. Glandular structures, when recognised as lymph glands are listed only as lymphadenopathy. Where there is doubt it is advisable to describe them as large opacities.

a. Large Opacities (>1cm)

Parenchymal opacifications are included in this category if their largest diameter is greater than 1 cm.

- **Type** : The opacities are described as round or irregular. A large round opacity may be oval or lobulated but has a sharp well-defined edge for at least two-thirds of its circumference and although it may overlie other structures appears discrete. A large irregular opacity is of any shape, but has poorly-defined margins, often fading into

surrounding tissues and may on occasions be an aggregation or confluence of several opacities which cannot be distinguished from one another.

- **Size** : The size of these opacities must be measured with a ruler (preferably a transparent one) and are categorised as 1-5 cm ; > 5cm ; or greater than the size of the upper zone.
- **Extent** : The extent of the opacification is recorded as "single", "few" when 2 to 5 are present and "many" when more than 5 are present.
- **Zones** : For recording purposes, the lung is divided into three zones bilaterally. The zones are defined by two imaginary horizontal lines equally spaced between the lung apex to the midpoint of the diaphragm on each side. Where an opacification crosses one of these lines then both zones are recorded as affected.

- **Special considerations** :
    - Linear abnormalities or lines should be included in this category. However whereas when the aspect ratio is less than one to four i.e. an opacity is more than four times longer than it is wide (linear), the diameter should be recorded.
    - There is potential for confusing a large pleural opacity as a parenchymal one. For clarification, where there is a 'white out' (no visible air-fluid level or other means of distinguishing a pleural from parenchymal opacities) the opacification should be regarded as a 'large opacity' and sized according to the above measurements. However, where a sharp medial edge to a large opacity suggests pleural fluid the anatomical diagnosis of pleural fluid/thickening should be made.
    - Large opacities are frequently accompanied by smaller surrounding opacifications which might qualify as small opacities. The predominant abnormality or primary abnormality should be recorded for that zone. Where the reader is unable to determine a predominant abnormality for that zone or when both large and small opacifications are equally evident for that zone, then both large and small opacifications should be recorded.

b. Small Opacities (<1cm)

Parenchymal opacifications are included in this category if their largest diameter is less than 1 cm.

- **Type** : Small opacities are described as round or irregular. Round opacities are discrete lesions that appear as though they can be metaphorically "lifted" from the radiograph with tweezers, and do not merge with surrounding opacities. This appearance is maintained even when the opacities overlie one another. There appear to be no lines or bands joining individual nodules and no evidence of "new air space" formation (small round or irregular black holes that look like the holes in honey combs). Small irregular opacities are more linear and cannot be circumscribed; that is, it is difficult to judge where one ends and the next begins. Some may appear as rings, others bands and others irregular opacities with ill-defined edges.
- **Size** : The size of small opacities are categorised as < 1.5mm ; 1.5mm to 3.5mm or 3.5mm to 1cm. Size should be measured with a transparent ruler. Where there are multiple small opacifications then the largest of these small opacifications is measured for size. Irregular opacities are more difficult to measure as they have ill-defined margins. However, an estimate of size should be attempted.

- **Profusion** : The profusion of small opacification is described as 1+, 2+ or 3+. 1+ is defined as opacities that are sparse but clearly evident on close inspection. When profusion is 2+, the abnormalities are easily seen but the intervening lung is also easily appreciated to be normal or unaffected. When 3+, the profusion is striking and small opacities might threaten to coalesce in parts. Each of these categories represents a range of appearances, as can be appreciated from the fact that profusion in the ILO/UICC Pneumoconiosis standard radiograph method employs a 14 point score for the equivalent purpose. Where possible, readers should consult the ILO/UICC Standard plates to gain experience of the 1/1, 2/2, and 3/3 profusions, which approximate with the 1+, 2+ and 3+ of the CRRS method. This should be done during the process of agreement between readers prior to the commencement of the survey.
- **Zones** : For recording purposes, the lung is divided into three zones bilaterally. The zones are defined by two imaginary lines horizontal lines equally spaced between the lung apex to the midpoint of the diaphragm on each side. Where an opacity crosses one of these lines then both zones are recorded as affected.

- **Special considerations** :
    - Where small nodules are especially numerous, and coalesce, the area may be better described as a single large irregular opacity. As suggested above, the predominant abnormality for that zone will be the large opacity, although other zones with less profusion and no coalescence may be described as having the small opacities.
    - When both a large and many small opacities are present in the same zone, both may be recorded.

c. Cavities

A cavity is defined as a lucency either partially or completely surrounded by parenchymal opacification.

- **Size** : Cavities are measured across their maximal diameter and in the case of a complex cavity, the largest measurable diameter should be recorded. A cavity is measured as 1cm - 5cm ; > 5cm or greater than the extent of the upper zone. Where there are multiple cavities then the largest visible cavity should be measured and recorded.
- **Extent** : The extent of the cavity is recorded as 'single' where there is a single visible cavity. Where there are 2 to 5 cavities, the extent is recorded as ' few'. Six or more cavities are described as 'many'.
- **Zones** : For recording purposes, the lung is divided into three zones bilaterally. The zones are defined by two imaginary lines horizontal lines equally spaced between the lung apex to the midpoint of the diaphragm on each side. Where a cavity crosses one of these lines then both zones are recorded as affected.

- **Special Considerations** :
    - Cavities of less than 1cm are not recorded due to the relative inaccuracy of recording and measuring small lucencies.

- Only cavities defined as stated above are defined as lucencies. Bullae, defined as air-filled sacs with very thin walls around most of their circumference, are considered below.

6. Pleural Abnormalities

This includes abnormalities of the pleura over the convexity of the lungs, the diaphragmatic and mediastinal surfaces. Normal pleura cannot be visualized on a chest radiograph. Calcification and visible plaques are recorded separately on the form. Differentiating pleural fluid from pleural thickening or fibrosis on a normal chest radiograph is often not possible.

- **Extent**. The extent of a pleural abnormality is expressed as a fraction of the lateral chest wall. The chest wall from the costophrenic angle to the first point of obvious inward curvature/deflection of the upper ribs is divided into quarters. The latter point is often difficult to determine and readers should agree on this method of quantitation prior to commencing the review of cases. The extent of abnormalities is described as involving < ¼; ¼- ½; or > ½ of the lateral chest wall. This is used for describing the extent of calcification/plaque and or pleural fluid/fibrosis.

- **Apical cap**. An apical cap was previously defined as extending from the first point of obvious inward curvature/deflection of the upper ribs at the lateral extent; to the point where the curved dome of the apex meets the mediastinal structures medially. This point is however difficult to locate in subjects with previous collapse surgery or triangulated thoracic cavities. A more accurate point of reference on the thoracic wall is to define the apex as extending laterally from the point at which the lateral edge of the 2nd rib meets the radiographic shadow of the lateral edge of the 3rd rib. Any pleural opacification of greater than 5mm depth/extent whether calcified or not, is designated an apical cap. The cap is described as present or absent.

7. Central Abnormalities

The central structures include the trachea, mediastinum, and the left and right hila. The hilum is the area between the mediastinum medially and the lung laterally, through which pass the bronchi, pulmonary and systemic vessels and accompanying connective and lymphatic tissues.

a. Tracheal Deviation

Tracheal deviation is measured at the entry of the trachea to the thoracic cavity, that is, at the level of the suprasternal notch (overlying the 4th thoracic vertebra). The trachea normally lies slightly to the right side as it moves alongside the aortic arch. Tracheal deviation can only be assessed from correctly centred radiographs.

b. Mediastinal Shift

To assess mediastinal shift, no less than 1/7 of the cardiac shadow should be visible to the right side of the centre point of the spinal column at the intersection of the diaphragm. In the

event of cardiomegaly this is more difficult to determine and consensus should be obtained by the readers on this abnormality.

c. Hilar elevation

The position of each hilum may be assessed in a variety of ways. Although the most accurate way is to determine the mid-hilar point on each side, this lies a few millimeters above the point at which the right and left main bronchi can be seen to enter from the mediastinum into the lung. The normal position of the right hilum is midway between the lung apex and the right cardiophrenic angle, and the left hilum is 1.5 cm higher than the right. In view of the difficulties associated with the assessment of the height of the hila, a hilum should only be recorded as elevated if:

- **On the right side**: It is more than 2 cm higher than the midpoint between the right lung apex and the right cardiodiaphragmatic angle and/or level with or higher than a normally positioned left hilum.
- **On the left side**: It is more than two centimeters higher than normal, and/or 3.5cm or more above a normally-located right hilum.
- Where both are potentially elevated, their positions relative to one another should not be considered in the assessment.

d. Lymphadenopathy

This includes, hilar or mediastinal lympadenopathy.
Lymph nodes in the hilum are recognized by their rounded or oval appearance, usually with well-defined borders, and their anatomical position. The position of bronchopulmonary, broncho-mediastinal, subcarinal, azygous, paratracheal and superior mediastinal positions must be memorized and practiced. Where there is doubt whether the mass is a lymph node, the suspected node may be described under large opacities.

8. Other Abnormalities

This section of the CRRS form is not purely descriptive, but relies upon pattern recognition of both anatomical structures and common pathologies. The section is divided into surgical, cardiac, skeletal and lung abnormalities. The presence of any of these abnormalities must be recorded

9. Radiograph completely normal

This section should only be completed with a “yes” if all other major subsections section responses on the form have been “no”. Note that a suboptimal film can be reported as normal. If any abnormality is noted on the radiograph i.e.: if there is a “yes” answer to any of the above subsections then the radiograph is not completely normal, and “no” should be crossed.

10. Abnormalities consistent with TB

This section is interpretive and any abnormality consistent with TB, whether interpreted as latent, active of otherwise should be noted as “yes”. Consensus for this section between readers because of its interpretive nature is essential.

Completed forms should not be folded, punched or stapled as this may obscure the data boxes and affect electronic/fax submission.

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