

# Standard Practice for Training in the Forensic Examination of Primer Gunshot Residue (pGSR) Using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry (SEM/EDS)

*Gunshot Residue SC  
Chemistry SAC  
Organization of Scientific Area Committees (OSAC) for Forensic Science*

## OSAC Proposed

# Standard Practice for Training in the Forensic Examination of Primer Gunshot Residue (pGSR) Using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry (SEM/EDS)

Prepared by Gunshot  
Residue Subcommittee  
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- Date:** March 12, 2020
- To:** Main Committee E30 members and Subcommittee E30.01 members (Concurrent Ballot)
- Tech Contact:** David Freehling, [dfreehling@ncdoj.gov](mailto:dfreehling@ncdoj.gov), 919-582-8920
- Work Item #:** WK58457
- Ballot Action:** Revision of “Standard Practice for Training in the Forensic Examination of Gunshot Residue (GSR) Using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry (SEM/EDS)”.
- Rationale:** The OSAC Subcommittee for Gunshot Residue Analysis has developed a standard practice for the training in the forensic examination of gunshot residue using SEM/EDS. This is the fourth time this new standard has been balloted at the subcommittee level. Negatives were found to be persuasive and comments from the previous ballots have been addressed.

## **Standard Practice for Training in the Forensic Examination of Primer Gunshot Residue (pGSR) Using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry (SEM/EDS).**

### **1. Scope**

- 1.1 This practice provides an outline of goals for a comprehensive training program in primer gunshot residue (GSR) analysis by scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM/EDS).
- 1.2 The primary purpose of this practice is to facilitate the development and implementation of training programs in crime laboratories or other such analytical entities that participate in the detection, analysis, and classification of primer GSR particles.
- 1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
- 1.4 The trainees and training program shall meet or exceed the minimum training requirements set forth in E2917.

## **2. Referenced Documents**

### 2.1 ASTM Standards

2.1.1 E1588 Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/  
Energy Dispersive X-Ray Spectrometry.

2.1.2 E1732 Standard Terminology Related to Forensic Science.

2.1.3 E2917 Standard Practice for Forensic Science Practitioner Training, Continuing Education,  
and Professional Development Programs.

### 2.2 Other Documents

2.2.1 Guide for Primer Gunshot Residue Analysis by Scanning Electron  
Microscopy/Energy Dispersive X-ray Spectrometry 11-29-11; SWGGSR.

## **3. Terminology**

3.1 Refer to ASTM E1588, E1732, and E2917 for terms relative to this Document.

## **4. Summary of Practice**

3.1 This practice provides a summary of the knowledge and skills to establish competency as an independent primer GSR analyst. These are to be used in conjunction with the laboratory's existing training protocols, standard operating procedures, and quality practices. It is intended as a practice for use by laboratory personnel responsible for training GSR analysts to prepare them to perform examinations using SEM/EDS to analyze samples for the presence of primer GSR.

3.2 This practice contains relevant suggested reading assignments and structured exercises for hands-on practical experience for the trainee.

3.2.1 Consider additional sources of information on primer GSR examination not specifically mentioned in this practice. Review new sources of information on general forensic methods and forensic GSR examinations on a regular basis to incorporate well-established current findings and methods into the training program and replace any outdated methods.

3.2.2 When possible, make additional training available to the trainee. Such training might include off-site short courses, short internships, and specialized training by experienced examiners. Additional training will provide a primer GSR examiner the opportunity to remain current in the field.

3.2.3 This practice focuses on the SEM/EDS examination of samples for primer GSR particles.

3.3 This practice sets out lessons, practical exercises, and methods of progress monitoring and trainee evaluation designed to be incorporated into an individual laboratory's training program. Topics for discussion occur between the trainee and the trainer.

- 3.4 A training program provides a theoretical foundation and basic practical skills to prepare a trainee to become a fully qualified forensic primer GSR examiner. At the end of the training program, the trainee, under supervision of a fully qualified examiner, interprets results, forms opinions, and presents and explains evidence based upon sound scientific knowledge, proper examination, and practical experience.
- 3.5 This training guide complements the SWGGSR Guide for Primer Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry <https://www.swggsr.org/publications<sup>2</sup>>.

#### **4 Significance and Use**

- 4.1 This practice is intended to be used by experts in the field of forensic science who have met their laboratory's technical requirements to be assigned to the role of trainer in the category of testing that deals with the detection, analysis, and classification of primer GSR particles.
- 4.2 The procedures outlined in this practice are grounded in the generally accepted body of scientific literature that exists in the field of forensic primer GSR examination.
- 4.3 Ensure that upon completion of this training program, the trainee gains the theoretical knowledge and practical skills needed to undertake and report the results of primer GSR examinations.
  - 4.3.1 Include the following for the forensic examination of primer GSR using SEM/EDS:
    - 4.3.1.1 Occurrence, transfer, and persistence of primer GSR;
    - 4.3.1.2 Contamination minimization and the prevention of loss of trace evidence;
    - 4.3.1.3 Other forms of trace evidence [such as deoxyribonucleic acid (DNA) and fibers] that could be associated with persons or exhibits that require sampling for primer GSR;
    - 4.3.1.4 Evidence recovery methods;
    - 4.3.1.5 Evidence handling procedures;
    - 4.3.1.6 Evidence packaging and documentation;
    - 4.3.1.7 Use and maintenance of SEM-EDS and auxiliary equipment;
    - 4.3.1.8 Quality assurance procedures;
    - 4.3.1.9 The analysis of primer GSR using SEM/EDS;  
Other techniques that have been/can be used to analyze GSR;
    - 4.3.1.10 The formation of primer GSR and other forms of GSR, such as organic GSR;
    - 4.3.1.11 Identification and classification of primer GSR;
    - 4.3.1.12 The demonstrated ability to differentiate between primer GSR and non-firearm, GSR-like particles;
    - 4.3.1.13 Interpretation of results;
    - 4.3.1.14 Preparation of scientific reports for potential inclusion as court evidence; and

4.3.1.15 Presentation of expert opinion evidence pertaining to primer GSR in court.

## **5 Syllabus**

5.1 Training guidelines provide the trainee theoretical knowledge and practical skills in primer GSR examination, analysis, and interpretation. Include a combination of the following training methods:

- 5.1.1 Reading of relevant literature;
- 5.1.2 Instruction by and observation of GSR examiners:
  - 5.1.2.1 Lectures and discussions;
  - 5.1.2.2 Demonstration of skills;
  - 5.1.2.3 Observation of case work; and
  - 5.1.2.4 Observation of expert court testimony.
- 5.1.3 Supervised practice of skills:
  - 5.1.3.1 Practical exercises and
  - 5.1.3.2 Assisting in and performing supervised casework.
- 5.1.4 Examinations and tests:
  - 5.1.4.1 Written and/or oral tests;
  - 5.1.4.2 Practical laboratory tests; and
  - 5.1.4.3 Mock/moot court.

5.2 This is an extensive training program and it is expected that an inexperienced forensic examiner would take approximately six months to one year to complete.

5.2.1 For the purpose of this practice, an inexperienced examiner is an individual who has little knowledge in trace evidence, minimal knowledge of SEM or EDS, and/or minimal knowledge of GSR evidence.

6.2.2 Portions of this training program can be substituted or removed based on the trainee's previous knowledge and experience of the theory or instrumentation related to this type of analysis.

## **6 Records of Training**

6.1 Refer to ASTM E2917 section 4-Documentation.

## **7 Responsibilities**

7.1 The trainer is technically competent in all aspects of the scientific discipline of primer GSR examination.

7.2 Responsibilities include:

- 7.2.1 Introducing the trainee to the relevant scientific literature, laboratory and technical procedures, training material, and appropriate reference collections;
- 7.2.2 Instruction in the laboratory evidence management systems;
- 7.2.3 Instruction in the documentation of casework;
- 7.2.4 Instruction in and discussion of the relevant scientific literature and theory pertaining to SEM/EDS and primer GSR with the trainee;

- 7.2.5 Instruction, guidance, and supervision of practical skills pertaining to:
  - 7.2.5.1 Contamination minimization and the prevention of loss of trace evidence;
  - 7.2.5.2 Evidence recovery methods;
  - 7.2.5.3 Evidence handling procedures;
  - 7.2.5.4 Evidence packaging and documentation;
  - 7.2.5.5 Use and maintenance of SEM/EDS and auxiliary equipment;
  - 7.2.5.6 Quality assurance procedures;
  - 7.2.5.7 The analysis of primer GSR using SEM/EDS;
  - 7.2.5.8 Other techniques that have been/can be used to analyze GSR;
  - 7.2.5.9 The formation of primer GSR and other forms of GSR;
    - Identification and classification of primer GSR;
  - 7.2.5.10 Interpretation of results;
  - 7.2.5.11 Preparation of scientific reports for potential inclusion as court evidence; and
  - 7.2.5.12 Presentation of expert opinion evidence pertaining to primer GSR in court.
- 7.2.6 Establishing and reviewing:
  - 7.2.6.1 Oral and written assignments or tests or both;
  - 7.2.6.2 Supervised case work tasks undertaken by the trainee.
- 7.3 The trainer monitors the trainee's progress to ensure thoroughness and completeness. The trainee meets the objectives set forth in the training program by:
  - 7.3.1 Self-study of reading materials;
  - 7.3.2 Demonstrating competence in the application of the practical skills covered by the training program;
  - 7.3.3 Successful completion of practical exercises;
  - 7.3.4 Successful completion of written or oral tests or both;
  - 7.3.5 Observation of and assisting in casework being conducted by an experienced examiner;
  - 7.3.6 Observation of court testimony given by an experienced examiner or reviewing transcripts in which primer GSR evidence was presented or both;
  - 7.3.7 Conducting themselves in an ethical and professional manner;
  - 7.3.8 Participating in the quality assurance and quality control program of the laboratory and, particularly, pertaining to primer GSR examinations, sampling and analysis using SEM-EDS;
  - 7.3.9 Successful completion of competency tests in the detection of primer GSR and subsequent interpretation and reporting of primer GSR results; and
  - 7.3.10 Demonstrating competency in supervised casework.

## 8 Training

- 8.1 The following sections of this practice provide recommendations and guidance in relation to the key issues of the laboratory's training program:
  - 8.1.1 Each section specifies the skill and knowledge to be gained in that particular subject as determined by the trainer and laboratory protocols, the trainee should demonstrate knowledge of specified topics by a combination of literature review, oral examinations, written examinations, and practical exercises.

- 8.1.2 Recommended literature provides the trainee with a sound theoretical background and solid foundation in topics necessary for primer GSR analysis. Additional References supplement the listed publications as available.
- 8.1.3 Demonstrate essential skills.
- 8.1.4 Design practical exercises to allow the trainee to learn and practice the skills needed to perform casework. Review the trainee's performance during the exercises to evaluate the trainee's ability to conduct primer GSR examinations and make conclusions. Document the performance of the trainee in all exercises.
- 8.1.5 Written or oral tests along with practical laboratory tests are recommended as a means of determining the trainee's comprehension of the material and to document the training. Design questions to test the trainee's theoretical and practical knowledge. Establish a pass criterion at the beginning of the training program.
- 8.1.6 Design simulated casework to demonstrate understanding of the various aspects of casework including: record keeping; processing of evidence; sample preparation; SEM/EDS analysis of prepared samples; and identification, classification, and interpretation of primer GSR evidence.
- 8.1.7 Administer a comprehensive competency test(s) before the trainee analyzes primer GSR cases independently. This mimics actual casework, requiring the trainee to demonstrate his/her knowledge of the laboratory's procedures in handling evidence, taking notes, maintaining chain of custody, and writing a report, as well as the actual examination of primer GSR evidence.
- 8.1.8 Provide the opportunity for the trainee to observe experienced examiners testifying in court when possible.
  - 8.1.8.1 Guide the trainee to pay attention to general courtroom procedures, the witness's appearance and demeanor, and the presentation of technical or expert knowledge.
- 8.1.9 Include a moot court exercise. The moot court mimics as closely as possible a real courtroom experience.
  - 8.1.9.1 Evaluate appearance, demeanor, and knowledge of the case, knowledge of the discipline, scientific accuracy, and presentation skills.
  - 8.1.9.2 Incorporate any local legal considerations, especially pertaining to expert witnesses and primer GSR testimony.
- 8.1.10 Monitor the trainee's progress according to objective criteria established by the laboratory.
  - 8.1.10.1 Conduct periodic progress assessments.
  - 8.1.10.2 Address deficiencies in the trainee's performance.
  - 8.1.10.3 Remediate through additional training and a reevaluation of the training program, if necessary.
  - 8.1.10.4 Continued deficiencies could suggest the unsuitability of the trainee for casework in this area.
- 8.2 Training Course Evaluation – Allow the trainee the opportunity to evaluate the primer GSR training program and the trainer. Address perceived deficiencies.
- 8.3 If permitted by laboratory policies and procedures, allow the trainee to participate in supervised casework.



- 8.3.1 Verify and document all laboratory results obtained by the trainee.
- 8.4 Provide authorization for casework upon successful completion of the training program, including competency test(s) and moot court.

## **9 Introduction to Primer GSR Evidence**

### 9.1 Include the following:

- 9.1.1 Types of primer GSR:
  - 9.1.1.1 Inorganic GSR and
  - 9.1.1.2 Organic GSR
- 9.1.2 Concepts and techniques of particle analysis relevant to primer GSR by SEM/EDS.

## **10 Primer GSR Formation**

### 10.1 Include the following:

- 10.1.1 Basic primer composition;
- 10.1.2 The physical processes involved in the initiation of the primer;
- 10.1.3 The chemical and physical processes that lead to the formation of primer GSR particles;
- 10.1.4 Particle morphologies;
- 10.1.5 Different types of firearms and how they vary in the emission of primer GSR;
- 10.1.6 Factors affecting the deposition and distribution of primer GSR:
  - 10.1.6.1 The shooter;
  - 10.1.6.2 The victim of a gunshot;
  - 10.1.6.3 Persons or items in the proximity of a firearm discharge; and
  - 10.1.6.4 The environment in which a firearm is discharged

## **11 Firearms/Ammunition**

### 11.1 Include the following:

- 11.1.1 Different types of firearms and their mechanisms;
- 11.1.2 Basic components of ammunition and their purpose and function, and how the chemical composition of how each contributes to primer GSR
  - 11.1.2.1 Bullet/projectile;
  - 11.1.2.2 Cartridge case;
  - 11.1.2.3 Propellant; and
  - 11.1.2.4 Primer
- 11.1.3 Various types of primers, including, at a minimum:
  - 11.1.3.1 Sinoxid;
  - 11.1.3.2 Rimfire; and
  - 11.1.3.3 Lead free
- 11.1.4 Typical primer components, their elemental composition and their purpose
  - 11.1.4.1 Shock-sensitive explosives or initiators;
  - 11.1.4.2 Sensitizers;
  - 11.1.4.3 Oxidizers;
  - 11.1.4.4 Fuels; and

#### 11.1.4.5 Frictionators

## 12 Retention and Transfer

- 12.1 Include the following:
  - 12.1.1 Factors that can affect the retention, redistribution, or loss of primer GSR particles including:
    - 12.1.1.1 The time since discharge;
    - 12.1.1.2 The physical characteristics of the surface on which the primer GSR particles have deposited; and
    - 12.1.1.3 The activity that that surface has been exposed to since discharge such as vigorous, physical activity, washing, and exposure to the environment.
    - 12.1.1.4 Transfer of primer GSR particles subsequent to the initial deposition from the discharge of a firearm.

## 13 Collection of Primer GSR Samples

- 13.1 Include the following:
  - 13.1.1 The various types of collection media including adhesive lifters, swabs, and vacuum filtration and their advantages and disadvantages.
  - 13.1.2 Presumptive field test kits for GSR, their limitations, advantages, and disadvantages.
  - 13.1.3 Impact of sampling environment, including the presence of moisture, blood, and soil on the collection of primer GSR particles.
  - 13.1.4 Proper collection techniques from the following, where applicable:
    - 13.1.4.1 Human subjects from the hands, face, hair, ears, and nose; and
    - 13.1.4.2 Clothing and inanimate objects

## 14 Contamination

- 14.1 Include the following:
  - 14.1.1 Potential sources of primer GSR contamination that can be encountered in the field (out of the laboratory) including police officers, squad cars transporting suspects, and objects in crime scene locations.
  - 14.1.2 Potential sources of primer GSR contamination that can be encountered in the laboratory, such as in exhibit storage, examination, and sample preparation areas.
  - 14.1.3 Contamination minimization and monitoring procedures.
  - 14.1.4 The potential for contamination and/or loss or destruction of other forms of trace evidence that could be associated with persons, clothing, or inanimate objects from which sampling for primer GSR is required and the possible impact on co-processing and sequential processing efforts for evidence such as DNA, fingerprints, and fibers.
  - 14.1.5 Procedures that can be used to minimize contamination, loss, or destruction of other forms of trace evidence when examining and sampling from persons, clothing, or inanimate objects from which sampling for primer GSR is required and capability to apply these procedures, if applicable.

## 15 Instrumentation and Analysis

### 15.1 SEM/EDS

15.1.1 Evaluate the trainee's ability to optimize SEM performance and SEM/EDS detection parameters for the automated analysis and detection of primer-inorganic GSR. Include the following, where applicable:

- 15.1.1.1 SEM electron gun filament saturation and filament replacement, where applicable;
- 15.1.1.2 SEM column alignment;
- 15.1.1.3 Understanding of SEM/EDS parameters for optimum imaging resolution to include accelerating voltage, beam current, condenser lens (CL) aperture selection (if so equipped), and final aperture (if interchangeable);
- 15.1.1.4 Understanding of EDS data collection to optimize for an automated analysis;
- 15.1.1.5 Knowledge of the current particle classification scheme in the manufacturer's EDS software for identifying detected particles;
- 15.1.1.6 Modification or addition of particle classes to the particle classification scheme, if allowed by the software;
- 15.1.1.7 Set up and optimization of SEM imaging;
- 15.1.1.8 Setting of stage positions to define the locations and analysis regions for any standards, reference materials, and the case specimen samples;
- 15.1.1.9 Set up of automated analysis run with appropriate reference materials to ensure that the SEM/EDS system will properly detect primer GSR particles;
- 15.1.1.10 Ability to evaluate the performance of the completed automated analysis to determine that the instrument was working properly; and
- 15.1.1.11 Storage of results from the automated analysis.

15.1.2 Evaluate the trainee's ability to perform manual examinations, relocation, and confirmatory analysis of particles detected by automated analysis. Include the following, where applicable:

- 15.1.2.1 Understanding of the laboratory protocols for the selection of specific primer GSR particle types and the quantity of detected particles requiring relocation and manual confirmatory analysis.
- 15.1.2.2 Set up of appropriate SEM/EDS parameters for manual imaging to show the particle size and morphology using backscattered electron and secondary electron imaging modes, as appropriate.
- 15.1.2.3 Set up EDS collection parameters of relocated particles to ensure that detected element peaks in the spectra are clearly identified.
- 15.1.2.4 Understanding of potential peak overlaps, particularly as they relate to elements detected in primer GSR particles. Include escape peaks, sum peaks, and system peaks.
- 15.1.2.5 Procedures for storing SEM images and EDS spectra obtained from the manual confirmatory analysis.

### 15.2 Sample Preparation

15.2.1 Include the conductive coatings of primer GSR adhesive lifters, where applicable.

- 15.3 Variable Pressure/Low Vacuum (VP/LV) SEM
  - 15.3.1 Include the following, where applicable:
    - 15.3.1.1 Knowledge of, and capability to, operate VP/LV SEM/EDS systems if the laboratory is so equipped;
    - 15.3.1.2 Advantages and disadvantages of using VP/LV mode rather than high-vacuum mode for primer GSR analysis; and
    - 15.3.1.3 Capability to adjust the vacuum to eliminate electrical charging issues on the specimen stub surfaces in VP/LV mode when no conductive coatings are applied.
- 15.4 Quality Assurance
  - 15.4.1 Include the following:
    - 15.4.1.1 Laboratory protocols for SEM/EDS maintenance and verification of performance;
    - 15.4.1.2 Environmental Control Samples; and
    - 15.4.1.3 Positive Primer GSR Controls and Reference Samples and their importance, use, and storage.

## **16 Interpretation and Reporting**

- 16.1 Include the following:
  - 16.1.1 Identification and classification of primer GSR particles by shape, morphology, and composition and understand the difference in significance between classes of primer GSR particles.
  - 16.1.2 Distinction between primer GSR and non-firearm, GSR-like particles, including the following:
    - 16.1.2.1 Cartridge Operated Tools;
    - 16.1.2.2 Air Bag Devices;
    - 16.1.2.3 Hand Grenades and “Flash Bang” Devices;
    - 16.1.2.4 Fireworks and Pyrotechnics;
    - 16.1.2.5 Brake Pads;
    - 16.1.2.6 Starter Pistols; and
    - 16.1.2.7 Pistol Style Marine Signal Flares
  - 16.1.3 Interpretation of particle population;
  - 16.1.4 Consideration of mechanisms of transfer of primer GSR particles; and
  - 16.1.5 Significance of no primer GSR particles being identified on a sample.
- 16.2 Awareness of occupations, hobbies, and activities in which primer GSR particles could be present, including the following:
  - 16.2.1 Law enforcement officers;
  - 16.2.2 Active duty military personnel;
  - 16.2.3 Hunters; and
  - 16.2.4 Gun enthusiasts or sport shooters.
- 16.3 Awareness of occupations, hobbies, and activities that could result in the presence of particles that could be confused with particles consistent with primer GSR, including, but not limited to, the following:
  - 16.3.1 Fireworks technicians;

- 16.3.2 Automobile mechanics;
- 16.3.3 Lead smelters; and
- 16.3.4 Construction workers.

## **17 Practical, Written and Oral Exercises**

- 17.1 Conduct training using a combination of the following methods:
  - 17.1.1 Instruction and demonstration by the trainer and other appropriate peers;
  - 17.1.2 Reading of relevant journal articles and texts;
  - 17.1.3 Supervised practical exercises;
  - 17.1.4 Written exercises, such as set assignments and examinations (question and answer); and
  - 17.1.5 Oral exercises, such as question and answer and mock court testimony. Document the training to enable an evaluator to assess the related knowledge and skills of the GSR trainee.
- 17.2 Evaluate the following technical skills:
  - 17.2.1 Collection of primer GSR samples from human subjects, clothing, vehicles, and other objects, if applicable;
  - 17.2.2 Preparation of primer GSR samples for analysis;
  - 17.2.3 Operation of SEM/EDS;
  - 17.2.4 Classification of primer GSR particles;
  - 17.2.5 Completion of practical exercises;
  - 17.2.6 Completion of competency test(s); and
  - 17.2.7 Evaluation of testimony in a moot court.
- 17.3 Include practical exercises such as the following:
  - 17.3.1 Observation of the analytical process;
  - 17.3.2 Analysis of a variety of samples, including known positive and negative primer GSR samples as well as the following:
    - 17.3.2.1 Automobile brake pads;
    - 17.3.2.2 Fireworks and pyrotechnics;
    - 17.3.2.3 Samples from persons having occupations of interest; and
    - 17.3.2.4 Samples related to time between discharge and collection

## **18 Evaluation**

- 18.1 An individual competent in the analysis of primer GSR performs the evaluation of the trainee.
- 18.2 Verify and document successful completion of the training program including the following:
  - 18.2.1 Practical exercises;
  - 18.2.2 Written exercises;
  - 18.2.3 Oral exercises;
  - 18.2.4 Independent studies;
  - 18.2.5 Supervised casework, where applicable;

- 18.2.6 Competency tests; and
- 18.2.7 Moot court testimony

## 19 Continuing Education

- 19.1 Refer to ASTM E2917 section 6-Continuing Education and Professional Development.

## 20 Keywords

- 20.1 EDS - energy dispersive X-ray spectrometer; GSR - gunshot primer residue; SEM - scanning electron microscope; training.

## 21 References

NOTE—The references cited are recommended for the purpose of acquiring the requisite foundational knowledge necessary for the successful completion of a training program in the analysis of primer GSR using SEM/EDS. This is not intended to be an exhaustive list. Encourage the trainee to search the literature for further relevant references.

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