34th Annual
In-Training Examination for Radiation Oncology Residents
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1. The Receiver Operating Characteristic (ROC) curve is a plot of the true positive rate against the false positive rate for the different possible cutpoints of a diagnostic test. Which of the following plots demonstrates the best test accuracy?

(A)  
(B)  
(C)  
(D)  

Key: B
Solution: The area under the ROC is a measure of test accuracy. The closer the curve follows the left-hand border and then the top border of the ROC space, the more accurate the test. The closer the curve comes to the 45-degree diagonal of the ROC space, the less accurate the test.

2. Two independent radiologists assess 100 chest X-ray for tuberculosis. Radiologist A identifies 50 abnormal X-rays and Radiologist B identifies 80 abnormal X-rays. Both radiologists agree on 60 X-rays. Which of the following statistical methods is the correct one to be applied?

(A) McNemar's test
(B) Chi-square test
(C) Kappa coefficient
(D) One way analysis of variance

Key: C

Solution: The Kappa coefficient is a widely used statistic for measuring the degree of reliability between different and independent raters. It compares the agreement against that which might be expected by chance. The Kappa coefficient ranges from 1 (perfect agreement) to -1 (complete disagreement).


3. What occurs if a true null hypothesis is rejected or if a difference is concluded when no difference exists?

(A) p-value
(B) Type I error
(C) Type II error
(D) Standard error

Key: B

Solution: A Type I error results if a true null hypothesis is rejected or if a difference is concluded when no difference exists.


4. Which of the following research designs are the quickest and least expensive studies to undertake?

(A) Clinical Trials
(B) Cohort Studies
(C) Case Control Studies
(D) Cross-Sectional Studies

Key: C

Solution: Case Control trials are ideal for examining rare diseases or conditions that develop over time. They are among the quickest and least expensive studies.

References: Saunders and Trapp, Basic & Clinical Biostatistics, 2nd Ed.
5. What problem is encountered when data sets in a meta-analysis are inappropriately combined?

(A) Compton Effect
(B) Simpson’s Paradox
(C) Westinghouse Effect
(D) Burali-Forti Paradox

Key: B
Solution: The Simpson’s Paradox is found when a trend appears in different groups of data but disappears when the data sets are combined.
References: Saunders and Trapp, Basic & Clinical Biostatistics, page 224-7, 2nd Ed.

6. Using a Kaplan-Meier estimator, the median PFS of a single-arm study was 15 months. How can this be interpreted?

(A) The total study duration was 30 months
(B) 15 months is the median of PFS time for patients who have progressed or died
(C) 15 months is the median of PFS time for patients who survived without progression
(D) 15 months is the earliest time at which the probability of the first occurrence of progression or death is 50% or less

Key: D
Solution: The Kaplan Meier curve is a right-continuous step function; therefore the median survival time is the time at which the step function reaches or crosses the 50% survival mark. In other words, it is the earliest time point at which the probability of survival is 50% or less (option D). Option A and B misinterpret population used in KM curves. Total study duration cannot be inferred from median survival time (option C).

7. Which of the following may be used as the primary endpoint in a phase II clinical trial?

(A) Cost effectiveness
(B) Disease control rate
(C) Adverse event rate
(D) Biological effective dose

Key: B
Solution: A phase II trial is designed to evaluate the short-term efficacy of a new drug or novel intervention, typically using objective response rate or disease control rate as the primary endpoint in cancer trials. Safety is important as a secondary objective in Phase II trials to determine the common adverse events. A dose-seeking design is used to establish the biological effective dose in a Phase I trial. Cost effectiveness analysis may be conducted within a clinical trial, but it cannot be the primary objective in an efficacy trial.
8. For a population of data, which statistical measure decreases as the number of samples increases?

   (A) Mean
   (B) Variance
   (C) Standard deviation
   (D) Standard error of the mean

**Key:** D

**Solution:** The standard error of the mean is the standard deviation of the distribution divided by the square root of the sample size. The greater the dispersion around the mean (standard deviation), the less certain the population mean and the greater the standard error of the mean. The larger the sample size the more confidence of the mean, the smaller the standard error of the mean.


9. In an epidemiologic study, 500 carbon-black workers with respiratory disease and 200 workers without respiratory disease were studied. Of those with disease, 250 reported exposure to carbon-black dust while only 50 without disease reported being exposed to the dust. This study is best described as a:

   (A) cohort study.
   (B) case-control study.
   (C) cross-sectional study.
   (D) randomized clinical trial.

**Key:** B

**Solution:** A case-control study looks backward in time to detect a cause to a particular outcome. A cohort study occurs over extended time to study a characteristic suspected of being a precursor to the effect and tries to answer what will happen. A cross-sectional study is a snapshot of what is happening at the moment. A randomized clinical trial looks at the result relative to the intervention.

10. Which of the following is influenced by the prevalence of disease in the population that is being tested?
   (A) Sensitivity
   (B) Specificity
   (C) True negative test
   (D) Positive predictive value

**Key:** D  
**Solution:** If we test in a high prevalence setting, it is more likely that subjects who test positive truly have disease than if the test is performed in a population with low prevalence. It is illustrated in below two examples; the total population is 100 subjects and there are same sensitivity and specificity but different prevalence of disease.

Example 1: Prevalence of disease=(10+5)/100=15%. Disease Status Present Absent Test Result Positive 10 40 Negative 5 45 Sensitivity=10/(10+5)=66.7%; Specificity=45/(40+45)=52.9%; Positive predictive values=10/(10+40)=20%; Negative predictive values=45/(5+45)=90%. Example 2: Prevalence of disease=(20+10)/100=30%. Disease Status Present Absent Test Result Positive 20 33 Negative 10 37 Sensitivity=20/(20+10)=66.7%; Specificity=37/(33+37)=52.9%; Positive predictive values=20/(20+33)=38%; Negative predictive values=37/(10+37)=79%. Using the same test in a population with higher prevalence increases positive predictive value.


11. The “power” of a test or study refers to which of the following?
   (A) The ability to detect a true difference
   (B) The confidence level selected to compare two data sets
   (C) The precision to which the mean of a distribution can be known
   (D) The accuracy to which the true mean of a distribution can be known

**Key:** A  
**Solution:** The power of a test is the probability of detecting a difference that exists. It can be stated as the probability of rejecting the null hypothesis when it is indeed false or, equivalently, concluding that the alternative hypothesis is true when it really is true. It is intimately related to the sample size used in the study.


12. A recent study reported a PFS hazard ratio of 1.25 for males versus females. What is the correct interpretation?
   (A) 25% lower risk of progression or death among males compared to females
   (B) 25% lower risk of progression or death among females compared to males
   (C) 25% higher risk of progression or death among males compared to females
   (D) 25% higher risk of progression or death among females compared to males

**Key:** C  
**Solution:** The hazard ratio is calculated by dividing the hazard of progression or death among males by that among females. The hazard of progression or death among males was 25% higher than females, or 1.25 times that of females (option C).

13. The probability of correctly rejecting the null hypothesis is called:

(A) Beta.
(B) Alpha.
(C) Power.
(D) Type II Error.

Key: B & C
NOTE: This item was multi-keyed for scoring purposes upon post-exam statistical item analysis (Both B and C were given credit as correct responses).

Solution: A Type I error (alpha) is when a true null hypothesis is rejected. A Type II error (beta) is when the null hypothesis is false (not truly an error). Power is the probability of rejecting a false null hypothesis and is equal to 1-beta.
References: Saunders and Trapp, Basic & Clinical Biostatistics, page 92-97. 2nd Ed.

14. 95% of the patients on a clinical trial weigh between 62 kg and 90 kg. Assuming the data is normally distributed, what are the mean and standard deviation?

(A) Mean: 66kg, Std Dev: 7 kg
(B) Mean: 76kg, Std Dev: 7 kg
(C) Mean: 66kg, Std Dev: 14 kg
(D) Mean: 76kg, Std Dev: 14 kg

Key: B
Solution: The mean is halfway between 62 kg and 90 kg: Mean = (62 kg + 90 kg)/2 = 76 kg 95% is 2 standard deviations either side of the mean (a total of 4 standard deviations) so: 1 standard deviation = (90 kg - 62 kg)/4 = 28 kg/4 = 7 kg
References: Saunders and Trapp, Basic & Clinical Biostatistics, 2nd Ed.
15. A new screening test for a certain disease is being evaluated. The table below shows the frequencies by the true disease status and screening test result.

<table>
<thead>
<tr>
<th>Screening Test Result</th>
<th>True Disease Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
</tr>
<tr>
<td>Positive</td>
<td>a</td>
</tr>
<tr>
<td>Negative</td>
<td>c</td>
</tr>
</tbody>
</table>

What is the specificity of a screening test?
(A) $a/(a+c)$
(B) $d/(b+d)$
(C) $a/(a+b)$
(D) $d/(c+d)$

**Key: B**

**Solution:** Screening refers to the application of test to people who as yet have no symptoms of a particular disease. It is classified as having a positive (disease likely) or negative (disease unlikely) finding. Diagnostic tests tell whether or not a subject actually has the disease. The performance of a screen test is considered by the sensitivity and specificity. The sensitivity is the percentage of subjects with disease who are classified as having disease and the specificity is the percentage of subjects without disease who are classified as not having disease. Those subjects with the disease should all be classified as having disease, and those subjects without the disease should be classified as not having disease. Therefore, a highly sensitive and specific test is preferred.


16. What is the appropriate stage grouping (AJCC, 7th Ed) for a patient status post R0 resection of a 12 cm high grade sarcoma of the anterior compartment of the thigh?
(A) IIB; pT2b cN0M0 G3
(B) IIB; pT3b cN0M0 G3
(C) III; pT2b cN0M0 G3
(D) III; pT3b cN0M0 G3

**Key: C**

**Solution:** Stage III includes large grade 3 tumors or node positive disease. T2= tumor greater than 5cm; a= superficial tumor; b=deep tumor. There is no T3 tumor grouping for soft tissue sarcoma.

17. Which clinical position will best allow treatment of a soft tissue sarcoma arising in the anterior compartment of the thigh?
   (A) Prone  
   (B) Supine  
   (C) Frog leg  
   (D) Lateral decubitus  

**Key:** C  
**Solution:** The extremity should be positioned to treat the region of the affected compartment with minimal treatment of uninvolved tissue. The anterior compartment is best treated with a “frog leg” position. The lateral decubitus position with the affected side closest to the couch and knee flexed will allow access to the posterior compartment.  

18. Spinal cord compression is optimally treated by:
   (A) SBRT  
   (B) RT alone  
   (C) Surgical decompression/stabilization + RT  
   (D) Surgical decompression/stabilization alone  

**Key:** C  
**Solution:** Prospective randomized data show that surgical + RT therapy provides superior results to surgery alone: Overall ambulation – 84% vs. 57% Duration of ambulation – 122 days vs. 57 days Regain of lost ambulation – 62% vs. 19% Survival – 126 days vs. 100 days The ASTRO Task Force recommends SBRT for spinal metastases and treatment of cord compression be treated in clinical trials.  

19. What dose and timing of radiation is used for heterotopic ossification prophylaxis?
   (A) 7-8 Gy as single Fx given < 72 hours pre-operatively  
   (B) 7-8 Gy as single Fx given < 72 hours post-operatively  
   (C) 18-20 Gy as single Fx given 24- 48 hours pre-operatively  
   (D) 18-20 Gy as single Fx given 24-48 hours post-operatively  

**Key:** B  
**Solution:** In a review on the role of radiation for heterotopic ossification prophylaxis, current standards include use of NSAIDS and single-fraction radiation treatment in range of 7-8 Gy given <4 hours preoperatively or <72 hours postoperatively.  
20. Which of the following systemic therapy agents can be used in the treatment of advanced or unresectable desmoid tumors?
   (A) Dasatinib
   (B) Pazopanib
   (C) Tamoxifen
   (D) Acetaminophen

**Key:** C

**Solution:** Per the NCCN guidelines: systemic therapy options for advanced or unresectable desmoid tumors (aggressive fibromatosis) include NSAIDs (sulindac or celecoxib), hormonal or biological agents (tamoxifen, toremifene, or low-dose interferon), chemotherapy (methotrexate and vinblastine, doxorubicin-based regimens), and TKIs (imatinib and sorafenib).


21. What are the breast and ovarian management recommendations for a woman with a CHEK2 mutation?
   (A) Screening breast MRI
   (B) Risk reducing tamoxifen
   (C) Risk reducing mastectomy
   (D) Risk reducing salpingo-oophorectomy

**Key:** A

**Solution:** For patients with CHEK2 mutations, the NCCN guidelines on genetic/familiar high risk assessment recommend annual screening mammogram and consideration for screening breast MRI. There is insufficient evidence for intervention to recommend risk reducing mastectomy, manage based on family history. There is no increased risk of ovarian cancer.


22. In patients with early stage breast cancer treated with breast conservation, what factors are associated with locoregional recurrence and not distant metastatic spread?
   (A) Size, ER status, Ki-67
   (B) Size, ER status, LVSI
   (C) Size, positive nodes, LVSI
   (D) Size, ER status, positive nodes

**Key:** A

**Solution:** The correct answer is A. Size, ER and Her2 status and Ki-67 are all predictors of local recurrence. Conversely positive nodal status and lymphovascular invasion are associated with systemic disease and preclude toward metastatic disease. Of note, a young age is also associated with a higher risk of local recurrence.

23. What is the stage for a 5 cm breast cancer with a clinically detected internal mammary node but no axillary nodes on ultrasound or physical exam, and without metastases?
   (A) IIIB
   (B) IIIA
   (C) IIIB
   (D) IIIC

   **Key:** B
   **Solution:** The correct answer is B. With a 5 cm mass she is a T2 and clinical internal mammary nodes in the absence of axillary nodes is a N2b. Per the AJCC 7th edition staging manual, the patient is a T2N2b, Stage IIIA.

24. In the ACOSOG trial Z0011, what was the approximate rate of regional nodal recurrence in the group treated with sentinel lymph node biopsy and no axillary lymph dissection?
   (A) 1%
   (B) 3%
   (C) 5%
   (D) 10%

   **Key:** A
   **Solution:** The results of Z0011 demonstrated only a 1% risk of recurrence in the group treated with SLNB alone versus the group treated with SLNB followed by axillary dissection. This was true in spite of the Z0011 study results showing an additional 27% of patients have involvement in undissected axillary nodes. With updated results, the cumulative incidence of nodal recurrences at 10 years was 0.5% in the AxLND arm and 1.5% in the SLN alone arm (p=0.28).

25. Which tumor markers can be used as adjunctive studies to assess for disease progression in metastatic breast cancer?
   (A) CEA, CA 15-3, CA 19.9
   (B) CEA, CA 15-3, CA 27.29
   (C) CEA, CA 19.9, CA 27.29
   (D) CA 15-3, CA 19.9, CA 27.29

   **Key:** B
   **Solution:** NCCN breast cancer guidelines include optional use of CEA, CA 15-3, CA 27.29 in the assessment of metastatic breast cancer. The ASCO guidelines on biomarkers to guide systemic therapy for metastatic breast cancer state that CEA, CA 15-3, and CA 27.29 may be used to assist in treatment decision-making, however should not be used alone for monitoring disease response. CA 19.9 is not used in breast cancer; more often in pancreatic cancer.
26. According to the 2009 ASTRO Guidelines, APBI patient selection suitable criteria includes:
   (A) ER negative tumors.
   (B) Tumor size less than 4 cm.
   (C) Patient age 45 years or older.
   (D) Invasive ductal histology without EIC component.

**Key:** D 
**Solution:** Smith et al, IJROBP 2009. According to the 2009 ASTRO consensus guideline on accelerated partial breast irradiation, suitable criteria include: age ≥ 60 y, no BRCA 1/2 mutation, T1 invasive ductal or other favorable histology, negative margins (≥2mm), no LVSI, ER positive, unifocal, no EIC, node negative, no neoadjuvant chemotherapy. Updates to these patient selection criteria have recently been published.


27. Per the AJCC (7th Ed) what is the stage of a 50 mm invasive breast carcinoma with 12 positive LNs?
   (A) Stage IIIA pT2N2
   (B) Stage IIIA pT3N2
   (C) Stage IIIC pT2N3
   (D) Stage IIIC pT3N3

**Key:** C 
**Solution:** Tumors >20 mm to <=50 mm in greatest dimension are T2. Pathologic nodal involvement of >=10 axillary lymph nodes is pN3 disease. Any N3 disease is stage IIIC.


28. Which biomarker can be used to guide adjuvant systemic therapy decisions early stage ER/PR positive/Her2 negative, node negative invasive breast cancer?
   (A) Ki-67 labelling index
   (B) Circulating tumor cells
   (C) CYP2D6 polymorphisms
   (D) 21-gene recurrence score

**Key:** D 
**Solution:** The ASCO clinical practice guideline on use of biomarkers to guide decisions on adjuvant systemic therapy for women with early-stage invasive breast cancer found high level evidence for use of the 21-gene recurrence score to guide decisions on adjuvant systemic therapy in ER/PR positive, Her2 negative node, negative breast cancer. Circulating tumor cells, tumor infiltrating lymphocytes, and Ki-67 labelling index should not be used to guide adjuvant therapy decisions. CYP2D6 polymorphisms should not be used to guide adjuvant endocrine therapy selection.

**References:** Harris et al. JCO 2016. 2016 34(10): 1134-1150.
29. According to a multidisciplinary consensus guideline, what is considered the standard for an adequate margin in DCIS treated with breast conservation?

(A) 1 mm  
(B) 2 mm  
(C) 5 mm  
(D) No tumor on ink

**Key:** B  
**Solution:** Use of a 2 mm margin is considered the standard for an adequate margin in DCIS treated with breast conservation therapy.  
**References:** Morrow et al. JCO. 2016 34:33, 4040-4046.

30. What is the common terminology criteria for adverse events (CTCAE) version 4 grade of radiation dermatitis in a breast cancer patient with extensive moist desquamation?

(A) Grade 1  
(B) Grade 2  
(C) Grade 3  
(D) Grade 4

**Key:** C  
**Solution:** Radiation dermatitis is an adverse reaction defined as the finding of cutaneous inflammatory reaction due to biologically effective levels of ionizing radiation. Grade 1: faint erythema or dry desquamation. Grade 2: moderate to brisk erythema; patchy moist desquamation mostly confined to skin folds and creases; moderate edema. Grade 3: moist desquamation in areas other than skin folds and creases; bleeding induced by minor trauma or abrasion. Grade 4: Life threatening consequences; skin necrosis or ulceration of full thickness dermis; spontaneous bleeding from involved site; skin graft indicated. Grade 5: death.  
31. What feature of DCIS correlates MOST with multicentricity?
   (A) Nuclear grade
   (B) Palpable mass
   (C) Size of index lesion
   (D) Histological subtype

**Key:** C

**NOTE:** This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores).

**Solution:** Frequency of multicentricity for DCIS in mastectomy specimens varies from 0-47%. The majority of these studies were reported prior to screening mammography and cannot be extrapolated to the small, mammographically detected lesions found today. In these studies, the frequency of DCIS was primarily related to the SIZE OF THE INDEX LESION. In the era of mammography screening, more recent studies have shown true multicentricity to be rare. Faverly et. al. showed 50% of mammographically screened lesions to be continuous. Discontinuous “gaps” were less than 5 mm in 82% of cases. Likelihood of “gaps” was related to the lesion’s differentiation; 90% of poorly differentiated lesions did not have gaps where as 30% of well differentiated lesions did. The most common histologic subtype associated with multicentricity is micropapillary.


32. What are the American Cancer Society screening guideline recommendations for women 45-54 years of age at average risk of breast cancer?
   (A) Annual mammography
   (B) Biennial mammography
   (C) Annual mammography and ultrasonography
   (D) Annual mammography and clinical breast examination

**Key:** A & D

**NOTE:** This item was multi-keyed for scoring purposes upon post-exam statistical item analysis (Both A and D were given credit as correct responses).

**Solution:** Per the ACS 2015 Guideline: “The ACS recommends that women with an average risk of breast cancer should undergo regular screening mammography starting at age 45 years (strong recommendation). Women aged 45 to 54 years should be screened annually (qualified recommendation). Women 55 years and older should transition to biennial screening or have the opportunity to continue screening annually (qualified recommendation). Women should have the opportunity to begin annual screening between the ages of 40 and 44 years (qualified recommendation). Women should continue screening mammography as long as their overall health is good and they have a life expectancy of 10 years or longer (qualified recommendation). The ACS does not recommend clinical breast examination for breast cancer screening among average-risk women at any age (qualified recommendation).” The NCCN breast cancer screening guidelines include a role for a clinical encounter that encompasses ongoing risk assessment, risk reduction counseling as well as a clinical breast exam. While there are no trials of clinical breast exam versus no screening, the NCCN guidelines state the rationale for the clinical encounter is to maximize earliest detection of interval breast cancers.

33. In patients with triple negative breast cancer and 1 to 3 positive LN treated with mastectomy, what was the effect of post mastectomy radiation therapy on LRFS and DFS?
   (A) Decreased LRFS, decreased DFS
   (B) Increased LRFS, decreased DFS
   (C) Decreased LRFS, increased DFS
   (D) Increased LRFS, increased DFS

**Key:** D

**Solution:** The correct answer is D. PMRT has been shown to be associated with increased LRFS and DFS particularly in high risk triple negative breast cancer, although the degree of benefit for these patients is lower than patients with luminal subtypes who derive an even greater benefit.

**References:** Chen et al. 2013. Radiotherapy can Improve the Disease-Free Survival Rate in Triple-Negative Breast Cancer Patients with T1-T2 Disease and One to Three Positive Lymph Nodes After Mastectomy. The Oncologist. Vol 18; 141-147.

34. According to a multidisciplinary focused guideline update, what is an indication for PMRT following neoadjuvant chemotherapy in patients with clinical stage I or II breast cancer?
   (A) Age
   (B) Presence of LVSI
   (C) Residual nodal disease
   (D) Residual DCIS in the breast

**Key:** C

**Solution:** PMRT is recommended in patients with persistent nodal disease following neoadjuvant chemotherapy as they have sufficiently high risk for locoregional recurrence. A recent ASCO/ASTRO/SSO focused update addresses the role for PMRT in patients with T1-2 tumors with 1-3 LNs positive with axillary LND, SLN biopsy, and use of neoadjuvant chemotherapy, and discusses regional nodal volumes should be treated.


35. A patient with cT4dN1M0 triple negative breast cancer and has no response to 3-cycles of neoadjuvant multidrug chemotherapy. What is the next step in her management?
   (A) Mastectomy with axillary node dissection
   (B) Comprehensive RT followed by mastectomy
   (C) Change chemotherapy and if still no response, proceed with RT
   (D) Counsel patient of very poor prognosis and advise supportive care

**Key:** C

**Solution:** If patient is not responding to chemotherapy, guidelines recommend changing chemotherapy and if a response proceed with mastectomy, or alternatively change chemotherapy and if still no response or progressive disease, proceed to RT. Given that the patient’s age and no evidence of metastatic disease, hospice is not an appropriate next step.


36. According to a population-based case-control study (Darby et al), what was the percent increase in the rate of major coronary events for each 1 Gy increase in mean heart dose?

(A) 1.4  
(B) 4.4  
(C) 7.4  
(D) 10.4  

**Key:** C  
**Solution:** Per Darby et al, the rate of major coronary event (MCE) increased by 7.4% for each increase of 1 Gy. The mean heart dose was a better predictor than the dose to the LAD.  

37. What is the most common site of metastatic spread in breast cancer?

(A) Bone  
(B) Liver  
(C) Lungs  
(D) Lymph nodes  

**Key:** A  
**Solution:** Breast can will metastasize to all listed sites as well as to the brain but the most common site is bone which was confirmed on autopsy studies.  

38. The most powerful pathologic predictor for DFS and OS for breast cancer patients is:

(A) tumor size.  
(B) Her 2 status.  
(C) histologic grade.  
(D) number of involved lymph nodes.  

**Key:** D  
**Solution:** Multiple clinical trials have repeatedly found the most important pathologic factors are number of axillary lymph nodes involved, tumor size, histologic type, histologic grade and lymph vascular space invasion. Of these factors, the single most powerful predictor is number of involved lymph nodes. Her2 Neu overexpression is associated with unfavorable tumor characteristics such as high nuclear grade and decreased expression of estrogen and progesterone receptors. It is associated with a decrease in DFS and OS.  
39. For a stage II breast cancer with 1-3 positive nodes, RT to the internal mammary nodes should be considered when the tumor location is in the:
   (A) axillary tail.
   (B) subareolar region.
   (C) upper outer quadrant.
   (D) lower outer quadrant.

**Key:** B  
**Solution:** Subareolar region is synonymous with central location. Also consider INM irradiation for 1-3 positive nodes in the setting of: young age, 20% or higher positive node ratio, extracapsular extension over 2 mm, and extensive lymphovascular space invasion.  

40. Per AJCC (7th Ed) involvement of which muscle is considered chest wall invasion in breast cancer?  
   (A) Serratus anterior  
   (B) Pectoralis major  
   (C) Pectoralis minor  
   (D) Latissimus dorsi

**Key:** A  
**Solution:** The chest wall includes the ribs, intercostal muscles, and serratus anterior muscle, not the pectoral muscles. Involvement of the pectoral muscles is not considered chest wall invasion per the AJCC staging for breast cancer.  

41. According to a multidisciplinary consensus guideline, what is considered the standard for an adequate margin for breast conserving surgery with whole breast RT in stages I and II invasive breast cancer?  
   (A) 1 mm  
   (B) 2 mm  
   (C) 5 mm  
   (D) No tumor on ink

**Key:** D  
**Solution:** Use of no tumor on ink is considered the standard for an adequate margin for breast conserving surgery with whole breast irradiation in stages I and II invasive breast cancer.  
**References:** Moran et al. JCO. 2014 32(14): 1507-1515.
42. What is the anticipated rate of LRC for locally advanced breast cancer treated with use of mastectomy, chemotherapy, and PMRT?
   (A) 25-35%
   (B) 40-50%
   (C) 65-75%
   (D) 80-90%

**Key:** D  
**Solution:** Based on the ACR Appropriateness Criteria for LABC patients treated with a combination of mastectomy and PMRT show an improvement in local control rates versus mastectomy and chemotherapy without PMRT. A multidisciplinary approach is favored for optimal outcomes.


43. Which criterion, per the 2011 ASTRO Guidelines regarding hypofractionation for whole breast RT, is acceptable?
   (A) Pathologic stage T1-2 N0
   (B) Patient has received chemotherapy
   (C) Dose homogeneity within +/- 10%
   (D) Patient is 40 years of age or older at diagnosis

**Key:** A
**Solution:** Patients are recommended to have T1 or T2 disease and to be node negative, to have not received systemic chemotherapy and to be 50 years or older at diagnosis. Dosimetry is recommended for a +/-7% homogeneity along the central axis (minimum dose 93%, maximum dose 107%).

**References:** Smith et al. IJROBP. P 59-68. Vol 81 N0.1, 2011.

44. What is the median survival (years) of low grade glioma patients on RTOG 9802 treated with RT followed by chemotherapy?
   (A) 7
   (B) 10
   (C) 13
   (D) 17

**Key:** C
**Solution:** RTOG 9802 randomized patients with grade 2 astrocytoma, oligoastrocytoma, or oligodendroglioma who were younger than 40 years of age and had undergone subtotal resection or biopsy or who were 40 years of age or older and had undergone biopsy or resection of any of the tumor to RT alone vs RT followed by 6 cycles of PCV chemotherapy. Patients who received radiation therapy plus chemotherapy had longer median overall survival than did those who received radiation therapy alone (13.3 vs. 7.8 years; hazard ratio for death, 0.59; P = 0.003).

45. What is the appropriate marginal dose (Gy) for single fraction SRS to a 1.0 cm WHO gr 1 meningioma?
   (A) 10
   (B) 14
   (C) 18
   (D) 22

   **Key:** B
   **Solution:** WHO gr1 meningiomas may be treated with SRS doses 12-16 Gy in a single fraction when appropriate.
   **References:** NCCN Guidelines 1.2016 Central Nervous System; Principles of Brain and Spinal Cord Tumor Radiation Therapy BRAIN-C 2

46. What is an appropriate dose (Gy) for conventional fractionated RT for a functioning pituitary adenoma?
   (A) 39.6
   (B) 45.0
   (C) 54.0
   (D) 59.4

   **Key:** C
   **Solution:** Fractionated radiation therapy: For nonfunctioning pituitary adenomas, 45–50.4 Gy delivered at 1.8 Gy daily fractions; for functioning pituitary adenomas, 50.4 –54 Gy delivered in 1.8 Gy daily fractions.

47. What was the chemotherapy used in RTOG 9802 (RT alone vs RT followed by chemotherapy for low grade glioma)?
   (A) Paclitaxel, Lomustine, and Vinblastine
   (B) Procarbazine, Lomustine, and Vincristine
   (C) Procarbazine, Irinotecan, and Carboplatin
   (D) Temozolomide, Irinotecan, and Vinblastine

   **Key:** B
   **Solution:** RTOG 9802 randmized patients with grade 2 astrocytoma, oligoastrocytoma, or oligodendroglioma who were younger than 40 years of age and had undergone subtotal resection or biopsy or who were 40 years of age or older and had undergone biopsy or resection of any of the tumor to RT alone vs RT followed by 6 cycles of Procarbazine, Lomustine (CCNU) and Vincristine chemotherapy. Patients who received radiation therapy plus chemotherapy had longer median overall survival than did those who received radiation therapy alone (13.3 vs. 7.8 years; hazard ratio for death, 0.59; P = 0.003).
48. The use of which medication may complicate the diagnosis of a suspected primary CNS lymphoma?

(A) Mannitol  
(B) Sodium  
(C) Albumin  
(D) Corticosteroids

**Key:** D  
**Solution:** Corticosteroids are cytotoxic to lymphoma, interfering with pathologic diagnosis.  

49. Per QUANTEC, what is the approximate risk (%) of radiation induced spinal cord myelopathy within 5 years of 50 Gy in 25 Fx?

(A) < 1  
(B) 3  
(C) 7  
(D) > 10

**Key:** A  
**Solution:** From QUANTEC: With conventional fractionation of 2 Gy per day including the full cord cross-section, a total dose of 50 Gy, 60 Gy, and ~69 Gy are associated with a 0.2, 6, and 50% rate of myelopathy.  

50. What were the results of the Malmstrom et. al. randomized trial (temozolomide alone vs. 34 Gy in 10 Fx vs. 60 Gy in 30 Fx) for newly diagnosed GBM in patients over 60 years of age?

(A) 60 Gy had worse OS compared to 34 Gy  
(B) 60 Gy had improved OS compared to 34 Gy  
(C) Temozolomide had better OS than either RT schedule  
(D) Patients with MGMT promoter methylation had improved OS with RT than temozolomide

**Key:** A  
**Solution:** In contrast to the Roa trial of 60 Gy in 30 vs. 40 Gy in 15 fractions (JCO 22, 2004) that found similar overall survival between the 2 radiotherapy schemes, this trial found inferior overall survival with 60 Gy compared to 34 Gy in 10 fractions. Malmstrom had median overall survival of 8.3 months for temozolomide alone vs. 7.5 months for 34 Gy in 10 fractions (p=0.24) and 6.0 months for 60 Gy in 30 fractions (p=0.01).  

51. What is the approximate local control following RT for orbital lymphoma?

(A) 25%  
(B) 50%  
(C) 75%  
(D) > 90%

**Key:** D  
**Solution:** In a series from the University of Florida, treatment of orbital lymphoma with doses ranging from 15-47.5 Gy (median 25.5 Gy), 5 yr local control was 98%.  
52. For which group of patients receiving SRS after WBRT improved OS?
   (A) NSCLC
   (B) 2-3 metastases
   (C) Single metastasis
   (D) Recursive partitioning analysis (RPA) Class I

**Key:** C

**Solution:** RTOG 9508 showed that SRS improved survival (median 6.5 vs 4.9 months, p=0.0393) in addition to WBRT in a preplanned analysis for patients with a single brain metastasis.


53. Which targeted agent has been shown in a phase II study to have efficacy in the treatment of recurrent/progressive atypical or anaplastic meningioma?
   (A) Sunitinib
   (B) Imatinib
   (C) Erlotinib
   (D) Nivolumab

**Key:** A

**Solution:** Platelet-derived growth factor receptors (PDGFRs; imatinib) and epidermal growth factor receptor (gefitinib and erlotinib) have not shown efficacy. A phase II study of imatinib in recurrent meningioma demonstrated a PFS6 of 0% in the atypical/anaplastic cohort. In a phase II trial of sunitinib, median PFS in this cohort was 5.2 months (95% CI: 2.8–8.3 mo), and median OS was 24.6 months (95% CI: 16.5–38.4 mo)


54. What is an appropriate dose (Gy) for single fraction SRS to a functioning pituitary adenoma?
   (A) 10
   (B) 14
   (C) 16
   (D) 20

**Key:** D

55. Which genetic syndrome is associated with an increased risk of developing pituitary adenomas?
   (A) NF-1
   (B) MEN-1
   (C) MEN-2
   (D) Li-Fraumeni

Key: B
Solution: MEN-1 is associated with pituitary, parathyroid and pancreatic islet cell tumors. MEN-2 is associated with medullary thyroid carcinoma and pheochromocytoma. NF-1 is associated with peripheral nerve sheath neurofibromas, café au lait spots, optic and intracranial gliomas. Li-Fraumeni Syndrome is associated with breast cancer, sarcomas and brain tumors.

56. The precentral gyrus is in the:
   (A) frontal lobe and is the motor cortex.
   (B) parietal lobe and is the motor cortex.
   (C) parietal lobe and is the sensory cortex.
   (D) frontal lobe and is the sensory cortex.

Key: A
Solution: The central sulcus divides the frontal lobe from the parietal lobe. Anterior to the central sulcus is the precentral gyrus (frontal lobe and motor cortex). Posterior to the central sulcus is the postcentral gyrus (parietal lobe and sensory cortex).

57. For elderly and/or frail patients with newly diagnosed GBM treated with RT alone, the IAEA randomized trial compared 25 Gy in 5 Fx versus 40 Gy in 15 Fx. What were the results of the 25 Gy arm of the study?
   (A) Inferior QoL
   (B) Inferior OS
   (C) Improved QoL
   (D) Non-inferior OS

Key: D
Solution: This IAEA trial randomized 98 elderly and/or frail (frail = age > 50 years and Karnofsky performance status [KPS] of 50% to 70%; elderly and frail = age > 65 years and KPS of 50% to 70%; elderly = age > 65 years and KPS of 80% to 100%) patients with newly diagnosed GBM to 2 radiotherapy fractionation schedules. There were no differences in overall survival time, progression-free survival time, and quality of life between patients receiving the two radiotherapy regimens. This trial builds upon the previous Roa trial (JCO 22:1583-1588, 2004) showing no difference in survival between 60 Gy in 30 fractions vs. 45 Gy in 15 fractions schedules.
58. What was the maximum tolerated dose (MTD) in Gy for SRS of tumors measuring 21-30 mm in the RTOG 9005 study?
   (A) 15  
   (B) 18  
   (C) 24  
   (D) 27

**Key:** B  

59. What factor is associated with longer PFS for patients with ependymoma?
   (A) Younger age  
   (B) Higher grade  
   (C) Spinal location  
   (D) 1p/19q codeletion

**Key:** C  
**Solution:** Ependymomas in the spine have a longer time to recurrence than either infratentorial or supratentorial tumors.  

60. Which molecular features of low grade gliomas are associated with improved OS?
   (A) Wild type IDH and mutant PIK3CA  
   (B) Mutant IDH and 1p/19q codeletion  
   (C) Wild type IDH and wild type PIK3CA  
   (D) Mutant IDH and no 1p/19q codeletion

**Key:** B  
**Solution:** The Cancer Genome Atlas comprehensive molecular profiling of lower grade glioma (LGG) characterized the aberrations associated with common histopathologic diagnoses. Patients with LGGs with wild type IDH had a median OS of 1.7 y. Patients with LGGs with mutant IDH and no 1p/19q codeletion had a median OS of 6.3 y. Patients with LGGs with mutant IDH and 1p/19q codeletion had median OS of 8.0 y. PIK3CA was not prognostic.  
61. What dose (Gy) is appropriate to treat Graves orbitopathy?
   (A) 2
   (B) 5
   (C) 20
   (D) 60

**Key:** C

**Solution:** Successful qualitative treatment outcome at 24 weeks was superior in patients receiving 10 fractions of 2 Gy versus 10 fractions of 0 Gy (placebo dose) in a randomized, double-blind, controlled trial.


62. What is the recommended radiation treatment after chemotherapy for primary CNS lymphoma?
   (A) 45 Gy WBRT if partial response to chemotherapy
   (B) 45 Gy WBRT regardless of response to chemotherapy
   (C) 23.4 Gy WBRT regardless of response to chemotherapy
   (D) 23.4 Gy WBRT if partial response followed by a cone-down to 45 Gy to residual disease

**Key:** D

**Solution:** From 2015 NCCN CNS guidelines: WBRT may be withheld in the primary setting in patients treated with chemotherapy. When used, WBRT doses should be limited to 23.4 Gy in 1.8 Gy fractions following a CR to chemotherapy. For less than a CR, consider 23.4 Gy WBRT followed by a limited field to gross disease of 45 Gy or focal radiation to residual disease only.

**References:** NCCN CNS guidelines (2015), and Morris. JCO 2013; 31:3971-3979.

63. Which tumor feature is suitable for episcleral plaque brachytherapy for uveal melanoma?
   (A) 5 mm height
   (B) Ring melanoma
   (C) Gross extrascleral extension
   (D) Involvement of more than half of the ciliary body

**Key:** A

**Solution:** Exclusion criteria based on the 2003 ABS guidelines

**References:** Nag, The American Brachytherapy Society recommendations for brachytherapy of uveal melanomas. IJROBP 2003 Jun 1; 56(2):544-55.
64. For patients with newly diagnosed GBM, following standard chemoRT (60 Gy in 30 Fx with concurrent temozolomide), compared to no tumor-treating fields (TTFields), the addition of adjuvant TTFields to maintenance temozolomide:
   (A) improved OS.
   (B) decreased PFS.
   (C) had non-inferior OS.
   (D) increased the incidence of seizures.

**Key:** A

**Solution:** 695 patients with newly diagnosed GBM were randomized to >18 hours per day of TTFields vs. no TTFields. The interim analysis included 210 patients randomized to TTFields plus temozolomide and 105 randomized to temozolomide alone, with a median follow-up of 38 months. Median progression-free survival (the primary endpoint) was 7.1 months with TTFields compared to 4.0 months in the temozolomide alone group (hazard ratio [HR], 0.62; P = .001). Median overall survival in the per-protocol population was 20.5 months in the TTFields plus temozolomide group and 15.6 months in the temozolomide alone group (HR, 0.64; P = .004). The incidence of seizures was 7% vs. 8% with and without TTFields.


65. Which one of these anatomic relationships render a pancreatic cancer unresectable?
   (A) Tumor abutment of the common hepatic artery < 180 degrees
   (B) Tumor abutment of the superior mesenteric artery
   (C) Solid tumor contact with the portal vein > 180 degrees
   (D) Solid tumor contact with the celiac axis > 180 degrees

**Key:** D

**Solution:** Unresectable disease includes >180 degree involvement with the SMA or celiac axis, as well as solid tumor contact with the first jejunal branch of the SMA and involvement of the celiac axis and aorta. Unreconstructible SMV/portal vein involvement is also unresectable. Less severe vascular involvement may be considered borderline resectable, but is not defined as unresectable.


66. What were the two treatment strategies compared in the CRITICS trial for resectable gastric cancer?
   (A) Neoadjuvant chemoRT vs. Adjuvant chemoRT
   (B) Perioperative chemotherapy vs. Neoadjuvant chemotherapy + Adjuvant chemoradiation
   (C) Neoadjuvant chemoRT + Adjuvant chemotherapy vs. Perioperative chemotherapy
   (D) Neoadjuvant chemotherapy + Adjuvant chemoradiation vs. Adjuvant chemoRT alone

**Key:** B

**Solution:** The CRITICS trial addressed whether postoperative chemoradiation would improve outcomes after preoperative chemotherapy, as compared to a strategy of perioperative chemotherapy alone (which had proven effective in the MAGIC trial).

67. What is the risk of local failure for a rectal cancer located in the high rectum (10-16 cm from the anal verge) treated with surgery alone according to the 11 year results of the German Rectal Trial (CAO/ARO/AIO-94)?
   (A) 2%
   (B) 5%
   (C) 7%
   (D) 10%

**Key:** D

**Solution:** The risk of local recurrence for high rectal tumors in patients who did not receive radiotherapy was 10.4%, 18.7% in mid-rectal tumors and 4.5% in tumors 0-5 cm from the anal verge.


68. According to the ACT II study for anal cancer, post-treatment clinical assessment with digital rectal examination is most predictive for long term outcome at which time point (weeks)?

   (A) 4
   (B) 8
   (C) 12
   (D) 26

**Key:** D

**Solution:** The ACT II study performed a secondary analysis evaluating the optimal timepoint to assess clinical tumor response after chemoradiotherapy. Among 940 patients enrolled in the study, complete clinical response was achieved in 492 (52%) of 940 patients at assessment 1 (11 weeks), 665 (71%) of patients at assessment 2 (18 weeks), and 730 (78%) of patients at assessment 3 (26 weeks). Based on these findings, the authors concluded that many patients who do not have a complete clinical response when assessed at 11 weeks after commencing chemoradiotherapy do in fact respond by 26 weeks, and the earlier assessment could lead to some patients having unnecessary surgery.


69. According to the updated results (2015) of the ARTIST trial for gastric cancer, which of the following is most likely to benefit from postoperative chemoRT?

   (A) Diffuse type, node-positive
   (B) Diffuse type, node-negative
   (C) Intestinal type, node-positive
   (D) Intestinal type, node-negative

**Key:** C

**Solution:** The ARTIST trial reported a significant improvement in disease-free-survival with adjuvant chemoradiation in the subsets of gastric cancer patients with node-positive disease, and with intestinal type tumors.

70. According to the CROSS randomized trial, preoperative chemoRT improves survival for which histologic subtypes of esophageal cancer?
   (A) Adenocarcinoma only
   (B) Squamous cell carcinoma only
   (C) Both adenocarcinoma and squamous cell carcinoma
   (D) Neither adenocarcinoma nor squamous cell carcinoma

   **Key:** C
   **Solution:** Preoperative chemoradiation was associated with a significant survival benefit for both histologic subtypes, although the magnitude of the benefit was greater for squamous cell carcinoma.
   **References:** Lancet Oncol. Shapiro J. 2015. 16(9):1090-8.

71. Compared to pancreatic head tumors, adenocarcinomas of the pancreatic body/tail:

   (A) are more likely to present with jaundice.
   (B) metastasize to similar lymph node regions.
   (C) are more likely to involve splenic artery lymph nodes.
   (D) have the same risk of distant metastases at presentation.

   **Key:** C
   **Solution:** Pancreatic body/tail adenocarcinomas have a greater rate of spread to splenic artery lymph nodes than pancreatic head adenocarcinomas (36% vs 2% in meta-analysis by Sun et al). Pancreatic body/tail adenocarcinomas have a greater propensity for distant metastatic disease at presentation than head adenocarcinomas. The meta-analysis by Sun et al. demonstrates distinct nodal regions at risk in pancreatic adenocarcinomas arising from the head and body/tail of the pancreas. Pancreatic body/tail adenocarcinomas have a lower rate of spread to superior mesenteric artery lymph nodes than pancreatic head adenocarcinomas (10% vs 16% in meta-analysis by Sun et al).

72. Which of the following is characteristic of classic radiation induced liver disease?

   (A) Jaundice
   (B) Hepatomegaly
   (C) Encephalopathy
   (D) AST/ALT 10 times above the normal limit

   **Key:** B
   **Solution:** Radiation induced liver disease is characterized by markedly elevated alkaline phosphatase and mildly elevated AST/ALT and has the typical triad of presenting symptoms is ascites, hepatomegaly, and elevated liver enzymes.
73. Which dosimetric threshold for the pelvic bone marrow is associated with > grade 2 neutropenia and leukopenia during cisplatin based radiation?
   (A) V10 > 90%
   (B) V20 > 70%
   (C) V30 > 50%
   (D) V40 > 30%

**Key:** A

**Solution:** Increased pelvic BM V(10) (BM-V(10)) was associated with an increased Grade 2 or worse leukopenia and neutropenia. Patients with BM-V(10) > or =90% had higher rates of Grade 2 or worse leukopenia and neutropenia than did patients with BM-V(10) <90% (11.1% vs. 73.7%, p < 0.01; and 5.6% vs. 31.6%, p = 0.09). No associations between HT and V(30) and V(40) were observed.


74. Concerning cholangiocarcinoma and biliary tract cancers:
   (A) liver transplant is an option for patients with intrahepatic cholangiocarcinoma.
   (B) the standard of care of unresectable biliary tract cancer is gemcitabine/cisplatin.
   (C) adjuvant chemoRT is indicated for T1N0 gallbladder cancer resected with negative margins.
   (D) FOLFIRINOX has been shown to improve OS over gemcitabine alone for unresectable cholangiocarcinoma.

**Key:** B

**Solution:** Liver transplant is only indicated for extrahepatic cholangiocarcinoma. FOLFIRINOX improves survival over gemcitabine alone for metastatic pancreatic cancer. The ABC trial showed improved survival with gemcitabine/cisplatin over gemcitabine alone. For early stage gallbladder cancer, adjuvant chemoradiation does not improve survival, based on SEER-Medicare data.


75. What did Tao et al. (JCO, 2016) report regarding the effect of RT for intrahepatic cholangiocarcinoma?
   (A) RT dose was not associated with overall survival
   (B) Radiation induced liver disease was the most common toxicity seen
   (C) High dose radiation produced local control rates similar to rates in surgical series
   (D) RT alone was associated with improved PFS compared to combined chemoradiation

**Key:** C

**Solution:** Radiation dose was the most important predictor of local control and overall survival. As a continuous variable, RT dose was associated with improved local control (p=0.03) and overall survival (p=0.02). Concurrent chemotherapy did not affect progression-free survival (p=0.34) on univariate analysis. No cases of radiation induced liver disease were reported. Biliary stenosis was the most commonly seen complication, but the authors comment that it is difficult to determine whether this was related to treatment or disease progression.

76. Regarding dose constraints when considering a 3-fraction SBRT regimen for a colorectal liver metastasis:

(A) the bowel Dmax of 45 Gy is acceptable.
(B) the mean liver dose should be kept < 30 Gy.
(C) the chest wall dose constraint should be V30 < 30 cc.
(D) the V15 of the normal liver parenchyma should be kept < 700 cc.

Key: C

Solution: The V15 is the amount of liver that receives above 15 Gy. 700 cc of normal liver should be kept below 15 Gy. Data from University of Virginia and University of Colorado suggested a chest wall dose constraint of V30<30cc to be associated with a lower rate of chest wall toxicity. Bowel Dmax of 45 Gy is too high. Similarly, a mean liver dose of 30 Gy is too high for an SBRT regimen.


77. What were the findings in RTOG 97-04 for adjuvant pancreatic cancer patients treated per protocol, versus those not treated per protocol?

(A) Not associated with any study outcome
(B) Significant improvement in median survival
(C) Significant decrease in gastrointestinal toxicity
(D) Compared to treatment arm, less correlation with median survival

Key: B

Solution: This paper demonstrated that median survival was associated with treatment per protocol (1.74 vs 1.46 years, p=0.0077, favoring per protocol treatment). No gastrointestinal toxicity data were reported; non-hematologic grade 4-5 toxicity in the gemcitabine arm showed a non-significant trend toward an increase with protocol deviation (6% vs 12%, p=0.065). On multivariate analysis, per protocol treatment vs less than per protocol treatment correlated more strongly with median survival than treatment arm (p=0.014 vs p=non-significant).


78. What is the TD5/5 for whole liver radiation?

(A) 20 Gy
(B) 30 Gy
(C) 40 Gy
(D) 50 Gy

Key: B

Solution: The mean liver doses associated with a 5% risk of classic RILD for primary and metastatic liver cancer are 28 Gy and 32 Gy, respectively, in 2 Gy per fraction.

References: Dawson LA, Ten Haken RF, Seminars in Radiation Oncology, (2005).
79. What was the study design of the SWOG 0809 biliary cancer study published by Ben-Josef et al. (JCO, 2015)?
(A) A single arm phase II study of chemoRT after surgery
(B) A single arm phase II study of chemotherapy plus chemoRT after surgery
(C) A randomized phase III study demonstrating the overall survival benefit of adjuvant chemoRT after surgery and chemotherapy
(D) A randomized phase III study demonstrating the lack of overall survival benefit of adjuvant chemoRT after surgery and chemotherapy

**Key:** B

**Solution:** The SWOG 0809 study is a single arm phase II study of gemcitabine and capecitabine chemotherapy plus chemoradiation with capecitabine after surgical resection of extrahepatic cholangiocarcinoma or gallbladder carcinoma.

**References:** Journal of Clinical Oncology. Ben-Josef. 2015; page 2617.

80. In order to be eligible for the ARTIST trial comparing adjuvant chemotherapy vs. adjuvant chemoRT, what type of gastric LND was required?
(A) D2 node dissection with R0 resection
(B) D2 node dissection with R0 or R1 resection
(C) D1 or D2 node dissection with R0 resection
(D) D1 or D2 node dissection with R0 or R1 resection

**Key:** A

**Solution:** Only patients undergoing D2 node dissection and no residual disease (R0 resection) were included in the ARTIST trial. The requirement for D2 dissection was important because the prior Intergroup 0116 (Macdonald et al.) trial of adjuvant chemoradiation included many patients who received only D0 or D1 dissection, raising the question of whether the benefit of adjuvant chemoradiation was due to suboptimal surgery.


81. For a solitary liver metastasis in Segment I of the liver treated to 50 Gy in 5 fractions, hotspots of 80 Gy can result in which injury?
(A) Biliary stenosis
(B) Portal vein thrombus
(C) Gallbladder perforation
(D) Hepatic artery dissection

**Key:** A

**Solution:** In a review of patients who received SBRT to tumors near the central biliary system, a high dose area >80 Gy resulted in increased risk for biliary stenosis.

82. Concerning anal cancer:
(A) the first echelon regional nodes are the inguinal nodes.
(B) most cases are associated with HPV serotype 18 and 33.
(C) dermal involvement of the vulva is considered M1 disease.
(D) it occurs in predominantly younger men who are HIV positive.

Key: C
NOTE: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores).

Solution: One study showed that HPV serotype 16 was found in 81% of anal cancer while serotype 18 and 33 were only found in 2.2% and 5.1%, respectively. Most cases occur in older female. AJCC staging describes first echelon nodes for anal cancer to be perirectal nodes. Dermal involvement of the vulva is M1 disease.


83. The high-dose chemoRT arm of the Intergroup 0123 trial for esophageal cancer had which outcome?
(A) Better OS
(B) Worse PFS
(C) Better locoregional control
(D) Higher treatment-related mortality

Key: D
Solution: There was no significant difference in survival or locoregional control between the two groups. More treatment-related mortality was observed in the high-dose group, though this did not appear to be related to the higher radiation dose.


84. In the 12-year follow-up of the Dutch study comparing TME with and without preoperative RT, which statement describes the results for patients with negative circumferential margins?
(A) There was no OS difference between surgery alone and preoperative RT
(B) The benefit of adding RT to surgery increased as the distance from the anal verge decreased
(C) There was no significant cancer specific survival benefit between preoperative RT compared to surgery alone
(D) The incidence of local recurrence was reduced by about 75% in the preoperative RT arm compared to surgery alone

Key: A
Solution: 10-year cumulative incidence of local recurrence was 5% in the group assigned to radiotherapy and surgery and 11% in the surgery-alone group (p<0.0001). The effect of radiotherapy became stronger as the distance from the anal verge increased. Patients assigned to radiotherapy had a lower overall recurrence and when operated with a negative circumferential resection margin, cancer-specific survival was higher. Overall survival did not differ between groups. For patients with TNM stage III cancer with a negative circumferential resection margin, 10-year survival was 50% in the preoperative radiotherapy group versus 40% in the surgery-alone group (p=0.032).

85. When is SBRT MOST appropriate in comparison to other types of liver directed therapies for hepatocellular carcinoma?

(A) 3 cm tumor with right portal vein thrombus
(B) Multifocal HCC involving both lobes of the liver
(C) 2 cm peripheral lesion in segment 6 of the liver
(D) 8 cm tumor in the central hilum of the liver with Child Pugh score 9

Key: A

Solution: Multifocal disease in both lobes of the liver is not an ideal candidate for SBRT given inability to spare normal liver parenchyma. Similarly, a large central lesion 8 cm in size with compromised liver function will be very difficult to treat due to poor liver tolerance. A small 2 cm peripheral lesion in the liver is best served with surgical resection, RFA or liver transplant. The 3 cm lesion with right portal vein thrombus is best suited for SBRT given its small size and poor suitability for other ablative modalities like radiofrequency ablation.


86. Which of the following is the correct AJCC staging for a patient with a 2 cm squamous cell carcinoma of the penis invading into the urethra with a single inguinal node with extracapsular extension?

(A) T2N1
(B) T3N1
(C) T2N3
(D) T3N3

Key: D

Solution: The correct staging is T3N3. Penile cancer staging is not based on size criteria. Involvement of the urethra represents T3 disease. A node with extracapsular extension is N3 disease.


87. A patient was recently found to have a recurrence of a high grade clinical stage T1 bladder tumor, following initial TURBT and BCG treatment. Which is the most reasonable treatment following confirmation that the tumor is a recurrent high grade cT1 tumor?

(A) Cystectomy
(B) Atezolizumab
(C) Balloon-occluded arterial infusion
(D) Bladder preservation with chemoRT

Key: A

Solution: The standard of care for recurrence of high grade T1 bladder cancer is a cystectomy. Bladder preservation in this setting is not standard, however is currently being pursued in the setting of a clinical trial, RTOG 0926. Atezolizumab is monoclonal antibody targeting the protein programmed cell death-ligand 1 (PD-L1), now approved for locally advanced or metastatic urothelial carcinoma. Balloon-occluded arterial infusion is a technique used for bladder preservation, especially in conjunction with radiation, in the setting of muscle invasive disease.

88. Which is an appropriate adjuvant treatment for a patient with Stage IIA seminoma with involvement of a single para-aortic lymph node?
(A) Observation
(B) RT to a para-aortic field to 20 Gy
(C) Chemotherapy with single agent carboplatin
(D) RT to a para-aortic and ipsilateral pelvic field

Key: D
Solution: Observation is an appropriate treatment for Stage I seminoma though treatment with single agent carboplatin or RT to a paraaortic field is also appropriate, however observation is not appropriate to patients with lymph node involvement so option A is incorrect. If a lymph node is involved both EP and BEP chemotherapy are appropriate but single agent carboplatin is not. Finally, since a lymph node is involved a paraaortic field is not appropriate and as such an extended “hockey-stick” approach is merited to cover the pelvic lymph nodes.

89. Under the new WHO (2016) grading (grade group) system for prostate cancer, a Gleason pattern of 4+3 would fall under which grade group category?
(A) 2
(B) 3
(C) 4
(D) 5

Key: B
Solution: The new grade group system is based on the Gleason score and provides an improvement in risk stratification compared to the composite Gleason score.
References: Moch H, Humphrey PA, Ulbright TM (2016) WHO Classification of Tumours of the Urinary System and Maile Genital Organs. WHO 4th, Reuter VE. (Eds).

90. Which of the following is considered an absolute CONTRAINDICATION to TRUS guided permanent brachytherapy for prostate cancer?
(A) Ataxia telangiectasia
(B) Gland size > 60 cm³
(C) History of prior pelvic RT
(D) Inflammatory Bowel Disease

Key: A
Solution: Ataxia Telangiectasia is often a contra-indication for the use of radiation in many disease sites and according to the American Brachytherapy Society (ABS) consensus for permanent prostate brachytherapy, is an absolute contraindication. The other including: a Gland >60 cm³, A history of inflammatory bowel disease and prior pelvic radiotherapy are considered relative contraindications by the ABS, with data suggesting permanent prostate brachytherapy can be performed if appropriately evaluated by an experienced team.
91. Which is most appropriate treatment for a Stage IV (cT2N1M0), Gleason 8 (4+4) adenocarcinoma of the prostate with an initial PSA of 25 ng/mL?
(A) Enzalutamide
(B) Single agent docetaxel
(C) EBRT with ADT for 2-3 years
(D) Radical prostatectomy with pelvic LND

**Key:** C  
**Solution:** Current NCCN recommendations for patients with regionally advanced (N1, M0) prostate cancer includes a category 1 recommendation for external beam radiation and Androgen Deprivation for 2-3 years. Surgery is not recommended for patients with clinical node positive disease at this time. Enzalutamide is indicated in the treatment of castrate resistant metastatic prostate cancer, as is Docetaxel.  
**References:** National Comprehensive Cancer Network., (2016) v.3.

92. Which high grade toxicity was observed in 6.6% of patients receiving 50 Gy in 5 Fx on a phase I/II dose escalated SBRT trial for localized prostate cancer?
(A) Rectal
(B) Urinary
(C) Erectile
(D) Hematologic

**Key:** A  
**Solution:** In a phase 1-2 dose escalated SBRT trial for localized prostate cancer, 6 patients (6.6%) in the highest dose level (50 Gy in 5 fractions) developed high grade rectal toxicity. (5 patients required colostomy) Grade 3+ delayed rectal toxicity was strongly correlated with volume of rectal wall receiving 50 Gy >3cc and treatment of >35% circumference rectal wall to 39Gy.  
**References:** Kim DW et al, Predictors of rectal tolerance observed in a dose-escalated phase 1-2 trial of stereotactic body radiation therapy for prostate cancer, Int J Radiat Oncol Biol Phys (2014) -page 509-517; 89(3).

93. What did the MRC TE 19 Trial, a randomized trial of RT versus single-dose carboplatin in adjuvant treatment of stage I seminoma, demonstrate?
(A) More lethargy with carboplatin
(B) Improvement in RFS carboplatin
(C) Decrease in 2nd germ cell tumors with carboplatin
(D) 30 Gy/10 Fx had better RFS compared to 20 Gy/10 Fx

**Key:** C  
**Solution:** The MRC TE 19 Trial, a randomized trial comparing carboplatin with radiotherapy (RT) as adjuvant treatment for stage I seminoma, found carboplatin had a non-inferior relapse-free rate compared to radiation. As well, there was less lethargy in patients receiving carboplatin, as compared to radiotherapy. The clinical equivalence of 30 Gy and 20 Gy had not been determined at the time of the trial initiation, but subsequently confirmed in the MRC TE 18 trial. Both fractionations were allowed in the TE 19 trial. Treatment with carboplatin resulted in a relative reduction in risk of nearly 80% (HR, 0.22; 95% CI, 0.05 to 0.95; P = .03) of contralateral germ cell tumors, as compared to those treated with radiotherapy.  
94. What is the PREFERRED imaging modality to identify a urethral defect secondary to urethral cancer?
   (A) PET
   (B) Pelvic CT
   (C) Endorectal ultrasound
   (D) Retrograde urethrogram

**Key:** D

**Solution:** Retrograde urethrogram is the gold standard to identify urethral defects.

**References:** Greene FL, Urethra, sixth edition, (2002).

95. Regarding clinically node-negative penile cancer, which management of the regional lymphatics confers the best OS?
   (A) Surveillance
   (B) Inguinal RT
   (C) Inguinal LND
   (D) Retroperitoneal LND

**Key:** C

**Solution:** Overall survival of ILND is 74%, inguinal RT 66%, surveillance 63%.


96. A 70-year-old undergoes a radical nephrectomy for a 7 cm renal cell carcinoma. The tumor was found to be invading into the surrounding perinephric tissues, the surgical margins were negative and it classified as stage III. What is the appropriate adjuvant management?
   (A) Nivolumab
   (B) Observation
   (C) Interleukin 2
   (D) RT to post-operative bed

**Key:** B

**Solution:** In patients with completely resected renal cell cancer the standard of care remains active surveillance with an abdominal CT or MRI within 6 months of surveillance initiation and then imaging at least annually.


97. What is abscopal effect?
   (A) Localized response following SBRT
   (B) Synergistic effect at the irradiated site
   (C) Systemic effects of immunosuppression
   (D) Therapeutic effect at a distance from irradiated site

**Key:** D

**Solution:** Abscopal effect has been reported especially when delivering SBRT to primary or metastatic renal cell carcinoma. Abscopal effect is therapeutic effect at a distance from irradiated site.

98. Which nodal regions should be included in the adjuvant radiation fields in a \( \geq pT3 \) bladder cancer with negative margins?

(A) Iliac  
(B) Inguinal  
(C) Presacral  
(D) Para-aortic

**Key:** A  
**Solution:** Local-regional nodal failure in patients with greater than or equal to \( pT3 \) disease and negative margins occurs in the iliac/obturator nodes and uncommonly in the cystectomy bed or presacral nodes.  

99. Which of the following characteristic increases the probability of PSA bounce after 125 I brachytherapy for the treatment of prostate cancer?

(A) Young age  
(B) Older age  
(C) > 50% positive cores  
(D) Prostate volume > 50cc

**Key:** A  
**Solution:** Young age was a predictor of PSA bounce in the Princes Margaret PSA kinetics analysis after I125 brachytherapy.  

100. Nivolumab (Optivo), approved for the treatment of advanced renal cell carcinoma, is a:

(A) BRAF inhibitor.  
(B) PD-1 inhibitor.  
(C) mTOR inhibitor.  
(D) CTLA-4 inhibitor.

**Key:** B  
**Solution:** Nivolumab (Optivo) is a humanized IgG anti PD-1 monoclonal antibody and works as an immune checkpoint inhibitor, blocking a signal that would have prevented activated T cells from attacking the cancer, thus activating the host immune system against cancer cells.
101. Regarding locally advanced prostate cancer, according to meta-analysis, how much did ADT add to RT improve OS?

(A) 0%
(B) 5%
(C) 10%
(D) 15%

**Key:** C  
**Solution:** Meta-analysis of 7 randomized trials performed by Bria et al.  

102. What percent of patients who undergo bladder preservation therapy will have a complete response on biopsy after initial TURBT and induction chemoRT?

(A) 40%
(B) 56%
(C) 69%
(D) 84%

**Key:** C  
**Solution:** A pooled analysis from the radiation therapy oncology group using six prospective bladder preservation studies revealed a complete response rate following chemoradiation of 69%.  

103. An elevation of which factor would best distinguish a non-seminomatous germ cell tumor (NSGCT) from a pure seminoma?

(A) LDH
(B) AFP
(C) Beta-HCG
(D) CA 19-9

**Key:** B  
**Solution:** Both Beta-HCG and AFP are elevated in NSGCTs, while only Beta-HCG is elevated in seminomas. Thus, answer C (AFP) is correct. LDH may be elevated in a number of inflammatory conditions and is used for prognostic impact. CA 19-9 is not classically elevated in germ cell tumors.  
104. What is the QUANTEC recommended maximum bladder V75 when planning for prostate cancer RT?
   (A) 5%
   (B) 15%
   (C) 25%
   (D) 35%

Key: C
Solution: In Quantec (Quantitative Analysis of Normal Tissue Effects in the Clinic) study of radiation dose-volume effects of a solid bladder include no more than 15% of the volume to receive a dose >80 Gy, no more than 25% of the volume to receive a dose >75 Gy, no more than 35% of the volume to receive a dose >70 Gy, and no more than 50% of the volume to receive a dose >65 Gy.

105. What is the outcome per RTOG 9910 of extending androgen suppression from 8 weeks to 28 weeks before RT in patients with localized prostate cancer?
   (A) Improved DSS rates
   (B) Improved OS rates
   (C) Decreased DM rates
   (D) No improvement in any endpoints

Key: D
Solution: Extending androgen suppression from 8 weeks to 28 weeks before radiotherapy did not improve outcomes at all.

106. What is the FIGO stage of a 4 cm carcinoma of the vulva with 8 mm of stromal invasion confined to the right labia majora and negative lymph nodes?
   (A) IA
   (B) IB
   (C) II
   (D) IIIA

Key: B
Solution: FIGO staging is a hybrid of clinical, surgical, and pathological staging. Stage I represents disease confined to the vulva. The current staging divides Stage I cancer into two divisions based on size with tumors > 2 cm as Stage IB. The subcategory also considers stromal invasion. Stage IA: lesions ≤ 2 cm confined to vulva or perineum with stromal invasion ≤ 1 mm Stage IB: lesions > 2 cm confined to vulva or perineum with stromal invasion > 1 mm
107. Per NCCN guidelines, what is the next management for stage cT1b2N0 squamous cell carcinoma of the cervix after pelvic RT with chemotherapy and intracavitary brachytherapy to the equivalent dose of 75 Gy?

(A) Observation  
(B) Cervical biopsy  
(C) Completion total hysterectomy  
(D) Consolidative carboplatin and paclitaxel chemotherapy  

**Key:** C  
**Solution:** Total dose > 85 Gy is recommended for primary chemoRT for Stage Ib2 cervical cancers. “Adjuvant” hysterectomy after partial course of brachytherapy can be considered for patients whose disease extent or pelvic anatomy preclude adequate coverage by brachytherapy.  
**References:** NCCN Clinical Practice Guidelines in Oncology, 1.2016 Cervical Cancer CERV-4.

108. What is the total recommended dose (EBRT + LDR equivalent brachytherapy) for a patient with positive vaginal margins following hysterectomy for endometrial cancer per ABS guidelines (Small 2012)?

(A) 45-55 Gy  
(B) 60-66 Gy  
(C) 70-80 Gy  
(D) 85-90 Gy  

**Key:** C  
**Solution:** The recommended dose for a patient with recurrent disease or positive margins is an LDR equivalent dose of at least 70-80 Gy. In a patient that is simply getting brachytherapy as a boost, the LDR equivalent total dose is 70 Gy to the vaginal surface. The other choices are either too low or too high.  

109. FIGO staging for a vaginal cancer with tumor involving lower third of the vagina and extending to para-vaginal tissues not but not pelvic side wall is:

(A) I.  
(B) II.  
(C) IIIA.  
(D) IIIB.  

**Key:** B  
**Solution:** FIGO staging for vaginal cancer with tumor extending to paravaginal tissues without side wall involvement is II. The stage III involves tumor extension to the side wall and is not divided into IIIA and IIIB.  
110. Regarding the National Cancer Database (NCDB) analysis of adjuvant therapy for carcinosarcoma of the uterus, chemoRT was associated with:
   (A) worse OS.
   (B) better OS.
   (C) worse LC.
   (D) no difference in OS or LC.

**Key:** B

**Solution:** The lowest hazard ratio observed was in patients that received adjuvant chemo-radiation.

**References:** Rauth-Hain, Patterns of care, predictors and outcomes of chemotherapy for uterine carcinosarcoma: A National Cancer Database analysis, Gynecologic Oncology 139 (2015) pages 84-89.


111. Which MRI sequence is considered standard for tumor visualization in brachytherapy treatment planning for cervical cancer?
   (A) T2
   (B) Pre-contrast T1
   (C) 3D gradient echo
   (D) Contrast-enhanced T1

**Key:** A

**Solution:** T2-weighted images sufficiently visualize organs at risk and tumor, while post-contrast T1-weighted sequence may overestimate tumor extension due to enhancement of peri-tumoral edema.

**References:** Dimopoulus, et al., Recommendations from GYN GEC-ESTRO working group: basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy, Radiother Oncol April 103 (1) 2012 pages 113-122.

112. What length (cm) of vaginal cuff is delineated in the CTV for adjuvant pelvic IMRT for endometrial cancer per consensus guidelines?
   (A) 0.5
   (B) 1.5
   (C) 3.0
   (D) 4.5

**Key:** C

**Solution:** The committee achieved a consensus CTV definition for postoperative therapy. The CTV should include the common, external, and internal iliac LN regions. The upper 3 cm of vagina and paravaginal soft tissue lateral to the vagina should be included in the CTV. For patients with cervical stromal invasion the presacral LNs should be included.

113. Regarding GOG 205 (Phase II trial) for locally advanced (T3/4) squamous cell carcinoma of the vulva with treatment of 57.6 Gy with weekly Cisplatin followed by surgical resection of residual tumor found:

(A) < 50% achieved clinical CR.
(B) unacceptable G3-4 toxicity.
(C) > 50 % achieved pathologic CR.
(D) anus and bladder preservation could not be achieved.

Key: C
Solution: Among 58 evaluable patients, there were 40 (69%) who completed study treatment. Reasons for prematurely discontinuing treatment included: patient refusal (N=4), toxicity (N=9), death (N=2), other (N=3). There were 37 patients with a complete clinical response (37/58; 64%). Among these women there were 34 who underwent surgical biopsy and 29 (78%) who also had a complete pathological response. Common adverse effects included leukopenia, pain, radiation dermatitis, pain, or metabolic changes. This combination of radiation therapy plus weekly cisplatin successfully yielded high complete clinical and pathologic response rates with acceptable toxicity.

114. What is the approximate risk of lower extremity lymphedema after robotic-assisted radical hysterectomy and pelvic LND?

(A) 10%
(B) 25%
(C) 40%
(D) 60%

Key: B
Solution: Lymphedema is one of common adverse events after pelvic lymph node dissection for cervical cancer. Notably, it probably does not depend on whether laparoscopic surgery was used instead of laparotomy.

115. Which pathology of the uterus includes a malignant epithelial component?

(A) Carcinosarcoma
(B) Leiomyosarcoma
(C) Endometrial stromal sarcoma
(D) Undifferentiated uterine sarcoma

Key: A
Solution: It is important to realize that a carcinosarcoma (also called Malignant Mixed Mesodermal Tumor or Malignant Mixed Mullerian Tumor) should be treated as a high grade endometrial cancer. The other options are malignant mesenchymal sarcomas.
116. What lymph nodes, in addition to the inguinofemorals should be included in the CTV when treating a vulvar primary that extends to the posterior wall of the proximal half of the vagina?
   (A) Obturator
   (B) Obturator, internal iliac
   (C) Obturator, internal and external iliac
   (D) Obturator, internal and external iliac, pre-sacral

   **Key:** D
   **Solution:** The distal vagina nodal coverage includes the inguinofemoral, obturator, internal and external iliacs. However if the posterior vaginal wall is involved then the presacrals from S1-S3 should be included due to drainage pattern.

117. What is the appropriate surgery for a cT1a2N0M0 cervical cancer in a postmenopausal patient?
   (A) Simple trachelectomy
   (B) Extrafascial hysterectomy
   (C) Cone biopsy with negative margins
   (D) Modified radical hysterectomy with LND

   **Key:** D
   **Solution:** Stage T1a in cervical cancer is further subdivided. A stage T1a1 has stromal invasion ≤ 3 mm in depth and extension ≤ 7 mm. A Stage IA2 has measured stromal invasion > 3 mm and not > 5 mm with an extension of not > 7 mm. Compared to T1a1, T1a2 requires use of more radical surgery with resection of at least medial parametrial tissues. Combination of pelvic radiotherapy and brachytherapy is an option for inoperable women.
   **References:** NCCN Clinical Practice Guidelines in Oncology, Cervical 1.2016 CERV-3.
118. What outcome is expected with the addition of concurrent chemotherapy to postoperative RT for cervical cancer (Peters, 2000)?

(A) Improvement in OS  
(B) No risk of severe GI toxicity.  
(C) Risk of non-completion of EBRT  
(D) No increase in hematologic toxicity

**Key:** A  
**Solution:** Patients with clinical stage IA2, IB, and IIA carcinoma of the cervix, initially treated with radical hysterectomy and pelvic lymphadenectomy, and who had positive pelvic lymph nodes and/or positive margins and/or microscopic involvement of the parametrium were studied in the Intergroup 0107 trial. Women were randomized to receive RT or RT + CT. Each group received 49.3 Gy in 29 fractions using standard pelvic fields. Chemotherapy consisted of -cisplatin 70 mg/m2 and a 96-hour infusion of fluorouracil 1,000 mg/m2/d every 3 weeks for 4 cycles, with the first and second cycles given concurrent to RT. Between 1991 and 1996, 268 patients were entered onto the study. Progression-free and overall survival was significantly improved in the patients receiving CT. While more patients in the chemoradiation arm had grade 3-4 GI and hematologic toxicity, rates of successfully completing the prescribed RT course were not different.  

119. What helps to improve visualization of vaginal tumor extension on MRI for cervical cancer?

(A) Introduction of a rectal balloon  
(B) Tripling the dose of IV gadolinium contrast  
(C) Insertion of a Foley catheter into the bladder  
(D) Application of ultrasound transmission gel into the vagina

**Key:** D  
**Solution:** Intravaginal application of high-signal intensity contrast media, such as ultrasound gel, unfolds vaginal fornices and helps to visualize direct vaginal wall invasion or exophytic tumor growth.  

120. What is the recommended frequency (months) of PAP smears following definitive RT for cT1bN0M0 cervical cancer?

(A) 6  
(B) 12  
(C) 24  
(D) Not indicated

**Key:** B  
**Solution:** While currently available evidence for utility of follow up Pap smears after radiotherapy is insufficient, surveillance cytology may be useful in detection of other lower genital tract neoplasms. Guidelines are the same for squamous cell and adenocarcinoma.  
121. Adjuvant treatment for a pathologic IB uterine papillary serous cancer should include: 

(A) observation.
(B) brachytherapy alone.
(C) endocrine therapy alone.
(D) chemotherapy with or without tumor-directed RT.

**Key:** D  
**Solution:** For these aggressive tumors multimodality care is recommended. For IB and higher chemotherapy with or without tumor-directed radiation is preferred. Endocrine therapy is not utilized in UPSC.  

122. Which lymph nodes, in addition to the common iliac lymph nodes, should be included in the postoperative CTV for a stage II endometrioid endometrial cancer? 

(A) Inguinal 
(B) External iliac 
(C) External and internal iliac 
(D) External and internal iliac and the presacral

**Key:** D  
**Solution:** The committee achieved a consensus CTV definition for postoperative therapy. The CTV should include the common, external, and internal iliac LN regions. The upper 3 cm of vagina and paravaginal soft tissue lateral to the vagina should be included in the CTV. For patients with cervical stromal invasion the presacral LNs should be included.  

123. What is the management for a pathologic stage T2bN0 adenocarcinoma of the cervix? 

(A) Radiation 
(B) Observation 
(C) Chemotherapy 
(D) Concurrent chemoRT

**Key:** D  
**Solution:** Patients with clinical stage IA2, IB, and IIA carcinoma of the cervix, initially treated with radical hysterectomy and pelvic lymphadenectomy, and who had positive pelvic lymph nodes and/or positive margins and/or microscopic involvement of the parametrium (such as this patient) were studied in the Intergroup 0107 trial. Women were randomized to receive RT or RT + CT. Each group received 49.3 Gy in 29 fractions using standard pelvic fields. Chemotherapy consisted of cisplatin 70 mg/m2 and a 96-hour infusion of fluorouracil 1,000 mg/m2/d every 3 weeks for 4 cycles, with the first and second cycles given concurrent to RT. Between 1991 and 1996, 268 patients were entered onto the study. Progression-free and overall survival was statistically significantly improved in the patients receiving CT.  
124. As a single modality in the adjuvant treatment of endometrial cancer, vaginal brachytherapy is as effective as pelvic RT in preventing local vaginal recurrences for FIGO stage:

(A) IB G2.
(B) IB G3.
(C) II G3.
(D) IIIA G2.

**Key:** A

**Solution:** Vaginal cuff brachytherapy is as effective as pelvic radiation therapy at preventing vaginal recurrence for patients with G1 or 2 tumors with >50% myometrial invasion or G3 tumors with <50% myometrial invasion. Patients with G3 cancer with >50% myometrial invasion or cervical stromal invasion may benefit from pelvic radiation to reduce the risk of pelvic recurrence. The best available evidence at this time suggests that reasonable options for adjuvant treatment of patients with positive nodes, or involved uterine serosa, ovaries, fallopian tubes, vagina, bladder, or rectum includes external beam radiation therapy as well as adjuvant chemotherapy.

**References:** Klopp, The Role of Postoperative Radiation Therapy for Endometrial Cancer: An ASTRO Evidence-Based Guideline, (2014) page 137-144

125. Per ASTRO consensus guidelines for contouring and treatment of cancer of the vulva, the CTV for the inguinal/femoral lymph node contours should extend what distance (mm) behind the femoral vessels?

(A) 0
(B) 5
(C) 8
(D) 10

**Key:** A

**Solution:** The ideal peri-vascular or radial margin (a margin that incorporates the location of all potential inguinal LNs) is not known. Margins around the nearest femoral vessel, as follows: anteromedial ≥35 mm, anterior ≥23 mm, anterolateral ≥25 mm, medial ≥22 mm. Lymph node recurrence is not seen posterior or lateral to femoral vessels - no need to add margins to the vessels in those regions.

126. A patient presents with a 4 cm level II left neck mass. Examination and laryngoscopy do not indicate any mucosal lesions. What is the appropriate sequence for the subsequent workup for an occult primary of the head and neck?

(A) PET/CT, FNA, EUA/tonsillectomy
(B) CT neck, FNA, EUA/tonsillectomy, PET/CT
(C) FNA, CT neck, EUA/tonsillectomy, PET/CT
(D) FNA, CT neck, PET/CT, EUA/tonsillectomy

**Key:** D

**Solution:** Tissue confirmation with FNA is the first step in work-up, as it will influence future imaging choices and management strategies. Incisional and excisional biopsies of the lymph node are discouraged as this disrupts fascial planes that are natural barriers to tumor spread. PET/CT prior to examination under anesthesia may detect the primary in 25% of patients with negative work-up after anatomic imaging and may limit the need to biopsy all mucosal sites or perform contralateral tonsillectomy. Tonsillectomy and biopsies can increase uptake in those mucosal areas on PET immediately after.


127. For early-stage (T1N0) squamous cell carcinoma of the oral tongue, elective neck dissection is considered when the depth of invasion is at least:

(A) 0-1 mm.
(B) 2-4 mm.
(C) 5-6 mm.
(D) > 6 mm.

**Key:** B

**Solution:** Most institutional series report that the rate of occult nodal disease in a clinical node-negative neck is approximately 20% or higher when the depth of invasion is greater than 2-4 mm.

**References:** NCCN Head and Neck guidelines, version 1.2016
128. What is MOST responsible for improved outcomes of oropharyngeal cancer over the last 30 years?
   (A) IMRT
   (B) Screening and early detection
   (C) Increased incidence of HPV+ disease
   (D) New systemic agents including cetuximab

**Key:** C

**Solution:** In the sample referenced, the portion of oropharyngeal cancers associated with HPV increased from about 15% in 1984 to 70% in 2004. HPV associated oropharyngeal cancers have much better outcomes, and the increasing incidence of HPV cancer in the oropharynx accounts for most of the improvement in outcomes over that time period.


129. What is the expected 2-year locoregional freedom from progression (FFP) rate following IMRT–based chemoRT for nasopharyngeal carcinoma?
   (A) 50%
   (B) 75%
   (C) 90%
   (D) 98%

**Key:** C

**Solution:** The development of IMRT techniques has proven especially beneficial for local control of advanced nasopharyngeal cancer patients. Whereas historical outcomes from treatment at centers of excellence yielded local control ranging from 50-70% for advanced tumor stage patients, the RTOG 0225 trial demonstrated improved outcomes (locoregional PFS 89.3%) and should serve as a benchmark.


130. Referred ear-pain from oropharyngeal cancer is most commonly mediated by branches of which cranial nerve?
   (A) V
   (B) VII
   (C) IX
   (D) X

**Key:** C

**Solution:** Branches of cranial nerve IX innervate both the ear (via the tympanic nerve) and the posterior 1/3 of the tongue and tonsillar fossae/pillars (via pharyngeal, lingual and tonsillar branches). Referred otalgia can also be mediated through cranial nerve V, more commonly for oral cavity and major salivary gland tumors. Cranial nerve VII and X are also involved in referred otalgia syndromes but not typically for oropharynx cancers.

131. Per AJCC (7th Ed), a squamous cell carcinoma of the oropharynx with multiple ipsilateral involved lymph nodes all ≤6cm, has an N-stage of:

(A) N1.
(B) N2a.
(C) N2b.
(D) N2c.

Key: C
Solution: N2b denotes metastasis in multiple ipsilateral lymph nodes, none more than 6cm in greatest dimension.

132. In the RTOG 91-11 laryngeal preservation trial, the addition of concurrent chemotherapy to RT did NOT improve:

(A) Overall survival.
(B) Locoregional control.
(C) Disease-free survival.
(D) Laryngeal preservation.

Key: A
Solution: The RTOG 91-11 trial compared three organ-preservation approaches to treating advanced squamous cell carcinoma of the larynx. These were induction cisplatin plus fluorouracil followed by radiotherapy, radiotherapy with concurrent cisplatin, and radiotherapy alone. The addition of concurrent chemotherapy to radiation therapy improved locoregional control, laryngeal preservation, and disease-free survival compared to radiation alone. Overall survival rates were not significantly different between the three arms of the study.

133. Of the following selections, which is the most common sinonasal cancer pathology?

(A) Melanoma
(B) Lymphoma
(C) Adenocarcinoma
(D) Esthesioneuroblastoma

Key: C
Solution: Sinonasal adenocarcinomas (including adenoid cystic carcinoma) may arise from respiratory surface epithelium or minor salivary glands and grouped together are the 2nd most common pathology in this disease subsite after squamous cell carcinoma.
134. Per AJCC (Ed. 7), what is the TNM stage for a nasopharyngeal carcinoma involving the left orbit with left level II, III, Va lymphadenopathy ≤ 6 cm and no evidence for DM?
   (A) T3N2bM0, Stage IVa
   (B) T4N2M0, Stage IVa
   (C) T4N1M0, Stage IVa
   (D) T3N2M0, Stage III

   **Key:** C

   **Solution:** Orbital involvement is stage T4 and ipsilateral only lymph node involvement is N1. T4N1M0 is overall stage IVA.


135. For the treatment of nasopharyngeal carcinoma, what sequencing of chemotherapy when added to RT provides the greatest survival benefit?
   (A) Adjuvant
   (B) Concurrent
   (C) Neoadjuvant
   (D) Chemotherapy does not improve survival

   **Key:** B

   **Solution:** The largest survival benefit is seen when chemotherapy is given concurrently with radiation therapy for the treatment of nasopharyngeal carcinoma. This was shown in a large meta-analysis that evaluated the benefit of chemotherapy given neoadjuvantly, concurrently, or adjuvantly. The largest survival and local-regional control benefit was seen when chemotherapy is sequenced concurrently with radiation.

   **References:** Langendijk, The additional value of chemotherapy to radiotherapy in locally advanced nasopharyngeal carcinoma: a meta-analysis of the published literature JCO 2004; 22(22): 4604-12.

136. Regarding the GORTEC 2000-01 trial for larynx and hypopharynx cancer, what was the benefit of the addition of docetaxel to induction cisplatin and 5-FU followed by RT?
   (A) Improved OS
   (B) Improved LRC
   (C) Improved DFS
   (D) Improved larynx preservation

   **Key:** D

   **Solution:** The addition of docetaxel to PF chemotherapy improved initial disease response and increased the portion of patients who received definitive radiation instead of laryngectomy. Overall survival, disease-free survival, and locoregional control rates were not improved with the addition of docetaxel.

A 62-year-old chronic smoker presents to the emergency room with epistaxis, diplopia, and headache. Physical examination indicates nasal obstruction and multiple bilateral neck masses. An abnormal CT scan examination is obtained, prompting an MRI examination of the skull base shown below. Based on the history and the image, which is the most likely cause of the patient’s diplopia?

(A) Carotid artery infiltration resulting in ischemic injury
(B) Infiltration of the right cavernous sinus causing trochlear (CN IV) nerve palsy
(C) Infiltration of the right cavernous sinus causing abducens nerve (CN VI) palsy
(D) Infiltration of the right cavernous sinus causing oculomotor (CN III) nerve palsy

Key: C

Solution: The provided image represents a case of newly diagnosed, advanced nasopharyngeal carcinoma presenting with diplopia caused by lateral rectus nerve palsy from invasion of the right cavernous sinus. This is a fairly common clinical presentation which should be recognized as a teaching point and one which may be encountered in clinical practice. It should be recognized that the anatomic complexity of the sixth nerve’s course, representing the longest course of any cranial nerve through the subarachnoid space makes it the most vulnerable for injury following cavernous sinus and/or clival involvement by malignancy.

138. In the Veterans Affairs (VA) Larynx Trial, the rate of salvage laryngectomy amongst patients with T4 larynx cancer was:
   (A) 16%
   (B) 36%
   (C) 56%
   (D) 76%

**Key:** C

**Solution:** The VA larynx trial was designed to test an organ-preservation approach for Stage III/IV larynx squamous cell carcinoma. Patients were randomized to receive a laryngectomy with adjuvant radiation therapy or induction cisplatin and 5-FU with radiation therapy for patients that achieve a partial response or better. The rate of salvage laryngectomy for patients with T4 larynx cancer was 56%.


139. Both DeCIDE and PARADIGM phase III trials tested the addition of induction chemotherapy to concurrent chemoRT in patients with locally advanced head and neck squamous cell carcinoma. What was the PRIMARY result of adding induction chemotherapy in these trials?
   (A) Improved OS
   (B) Improved PFS
   (C) Improved distant failure-free survival
   (D) Increased incidence of adverse events

**Key:** D

**Solution:** Induction chemotherapy did not improve any survival outcomes and was associated with more serious adverse events.


140. Cancer involving which oral cavity subsite has the best prognosis?
   (A) Lip
   (B) Oral tongue
   (C) Floor of mouth
   (D) Alveolar ridge

**Key:** A

**Solution:** According to SEER data from 2006-2012 5 year survival for patients diagnosed with lip cancer is 89%. For the oral tongue, it is 64.8%. For floor of mouth it is 52.4%. For Gum and other parts of the mouth it is 59.2%.

**References:** seer.cancer.gov, SEER data, (2016) NIH.
141. The overall larynx preservation rate in the Veterans Affairs (VA) Larynx Trial was:

(A) 25%.
(B) 52%.
(C) 64%.
(D) 85%.

**Key:** C

**Solution:** The VA larynx trial was designed to test an organ-preservation approach for Stage III/ IV larynx squamous cell carcinoma. Patients were randomized to receive a laryngectomy with adjuvant radiation therapy or induction cisplatin and 5-FU followed by radiation therapy for patients that achieve a partial response or better. The larynx preservation rate was 64%. Laryngectomy was required for 18% of patients after chemotherapy and 17% of patients after radiation therapy.


142. Per QUANTEC, which of the following best represents expected optic neuropathy rates following conventionally fractionated irradiation of the optic nerve and chiasm?

(A) 5% at < 55 Gy and 10% at 55-60 Gy
(B) < 3% at < 60 Gy
(C) < 3% at < 55 Gy and 5% at 55-60 Gy
(D) 10% at < 50 Gy

**Key:** C

**Solution:** The QUANTEC dose-volume limit summary lists optic neuropathy rates of <3% for 55 Gy, 3-7% for 55-60 Gy, and 7-20% for 60 Gy.


143. Which primary salivary tumor would be expected to have the lowest rate of occult nodal metastases?

(A) Adenocarcinoma
(B) Adenoid cystic carcinoma
(C) Salivary ductal carcinoma
(D) High-grade mucoepidermoid carcinoma

**Key:** B

**Solution:** The incidence of occult cervical lymph node metastases in patients with a clinically N0 neck, is highest amongst high-grade histological subtypes. The study by Chen et al. in 2007 and updated in 2014 shows that adenocarcinoma and high-grade mucoepidermoid carcinoma have high rates of occult nodal metastases of approximately 35%. Salivary ductal carcinoma is a high-grade histology with a high-rate of local-regional and distant failure. The incidence of occult nodal metastases for adenoid cystic carcinoma is lowest compared to these other histological subtypes.

144. According to QUANTEC, what is the risk of aspiration after a mean laryngeal dose of < 50 Gy when delivered with chemotherapy?

(A) < 5%
(B) < 10%
(C) < 30%
(D) < 50%

**Key:** C

**Solution:** Per QUANTEC the risk of aspiration after a mean laryngeal dose of < 50 Gy is 30% based on a single paper.


145. Which study treated early stage (T1-2 N0-1) oropharyngeal squamous cell carcinoma with 66 Gy in 30Fx?

(A) DAHANCA 6
(B) EORTC 22791
(C) RTOG 00-22 (Eisbruch)
(D) Intergroup 0099/RTOG 88-17 (Al Sarraff)

**Key:** C

**Solution:** RTOG 00-22 was a phase II trial that treated early stage oropharyngeal cancers with 66 Gy in 30 fractions. DAHANCA 6 compared 6 vs. 5 fractions per week for laryngeal cancer. Intergroup 0099 established chemoradiation as standard of care for advanced nasopharyngeal cancer. EORTC 22791 compared hyperfractionation (1.15 Gy BID) to conventional fractions (2 Gy daily).

A 38-year-old Asian woman presents with nasal obstruction, epistaxis, and rapidly enlarging bilateral neck masses. Neck biopsy demonstrates non-keratinizing squamous cell carcinoma of the nasopharynx. Which of the following BEST describes the abnormality shown by the arrow on the image below?

(A) LEFT level IIA node.
(B) LEFT medial retropharyngeal node.
(C) LEFT lateral retropharyngeal node.
(D) Direct extension of mucosal primary tumor.

Key: C

Solution: Nasopharyngeal carcinoma has the highest incidence of a cervical lymph node metastasis amongst primary tumors of the head and neck. The retropharyngeal lymph node chain is regarded as a common route of lymph node involvement in NPC. Involvement of the retropharyngeal lymph node chains carries prognostic significance in this tumor and therefore should be recognized by the clinician. Involvement of the lateral retropharyngeal nodal chain is much more common than the medial counterpart.

147. Intermittent intense sun exposure (sunburns) is MOST associated with an increased risk for which type of skin cancer?
   (A) Melanoma
   (B) Kaposi’s sarcoma
   (C) Basal cell carcinoma
   (D) Squamous cell carcinoma

   **Key:** A

   **Solution:** The type sun exposure impacts the relative risk of the various skin cancers with squamous cell carcinoma common after chronic sun exposure. Melanoma has the greatest increase in relative risk in people who experience sunburns. Kaposi’s sarcoma is not related to sun exposure.


148. A patient presents with multiple previously excised squamous cell skin cancers of the face and progressive numbness along the right medial cheek. Perineural spread to which structure explains the findings?
   (A) Vidian nerve
   (B) Gasserian ganglion
   (C) Supraorbital nerve
   (D) Infraorbital nerve

   **Key:** D

   **Solution:** Perineural spread from cutaneous malignancies represents an important clinical paradigm, which is increasingly encountered as a result of immunosuppression and increasing life expectancy and sun exposure. The patient above has isolated infraorbital nerve dysfunction. Gasserian ganglion, supraorbital nerve, and Vidian nerve involvement are excluded by the provided history (i.e. V1/V3 are intact, and there is no facial nerve compromise).


149. What is the next step for a patient who undergoes thyroidectomy for papillary thyroid cancer and has distance metastases on cross-sectional imaging?
   (A) RAI therapy
   (B) 123 I imaging
   (C) SBRT to oligometastases
   (D) Levothyroxine treatment

   **Key:** B

   **References:** NCCN Guidelines Thyroid, version 1.2016.
150. Regarding palliation for metastatic NSCLC with painful bony metastases, RTOG 9517 (Hartsell), a single Fx of 8 Gy as compared to 30 Gy in 10 Fx has:

(A) equivalent pain and narcotic relief at 3 months.
(B) higher rate of acute treatment-related toxicity.
(C) higher incidence of treatment related pathologic fracture.
(D) more rapid overall response rate on pain and narcotic relief.

Key: A
Solution: The 8 Gy delivered in a single treatment fraction was investigated if provides pain and narcotic relief that is equivalent to that of the standard treatment course of 30 Gy delivered in 10 treatment fractions over 2 weeks. Both regimens were equivalent in terms of pain and narcotic relief at 3 months and were well tolerated with few adverse effects. Grade 2-4 acute toxicity was more frequent in the 30-Gy arm (17%) than in the 8-Gy arm (10%) (difference = 7%, 95% CI = 3% to 12%; P = .002). Late toxicity was rare (4%) in both arms. The overall response rate was 66%. Complete and partial response rates were 15% and 50%, respectively, in the 8-Gy arm compared with 18% and 48% in the 30-Gy arm (P = .6). At 3 months, 33% of all patients no longer required narcotic medications. The incidence of subsequent pathologic fracture was 5% for the 8-Gy arm and 4% for the 30-Gy arm. The retreatment rate was statistically significantly higher in the 8-Gy arm (18%) than in the 30-Gy arm (9%) (P < .001).


151. Following surgery for lung cancer, a patient was found to have a 4.6 cm adenocarcinoma, a second 1 cm focus in the same lobe, and a level 10 lymph node demonstrating metastatic disease. What is the correct T and N stage (AJCC 7th Ed) for this patient with M0?

(A) T2aN1 (stage IIA)
(B) T3N1 (stage IIIA)
(C) T3N2 (stage IIIA)
(D) T4N2 (stage IIIB)

Key: B
Solution: AJCC 7th edition now incorporates size of the primary and distinguishes between where the second cancer is found (lobe versus separate lobe). Lymphovascular space involvement and extranodal extension can increase the risk of local and regional disease recurrences but are not included in the staging system. Level 10 is defined as a hilar node and is consider N1, although in years’ past it was typically lumped in with patients with mediastinal lymph node involvement.

152. Regarding the combination of memantine and whole brain radiation (RTOG 0614) in the management of brain metastases, memantine is:

(A) an antimetabolite and antifolate drug.
(B) associated with improved local control.
(C) associated with significantly higher grade 3 and higher morbidity.
(D) used to reduce the rate of decline in memory and processing speed.

Key: D
Solution: The RTOG 0614 trial enrolled adult patients with brain metastases who received WBRT and were randomized to receive placebo or memantine (20 mg/d), within 3 days of initiating radiotherapy for 24 weeks. Memantine is a noncompetitive, low-affinity, open-channel blocker that has been shown to be neuroprotective in preclinical models. Serial standardized tests of cognitive function were performed. Of 554 patients who were accrued, 508 were eligible. Grade 3 or 4 toxicities and study compliance were similar in the 2 arms. There was less decline in delayed recall in the memantine arm at 24 weeks (P = .059), but the difference was not statistically significant, possibly because there were only 149 analyzable patients at 24 weeks, resulting in only 35% statistical power. The memantine arm had significantly longer time to cognitive decline (hazard ratio 0.78, 95% confidence interval 0.62-0.99, P = .01); the probability of cognitive function failure at 24 weeks was 53.8% in the memantine arm and 64.9% in the placebo arm.


153. Regarding RTOG 0915 (Videtic) which compared two SBRT fractionation regimens (34 Gy in 1 Fx vs 48 Gy in 4 Fx), the single fraction treatment demonstrated:

(A) a worse primary tumor control at 1 year.
(B) a similar grade 3 or higher events at 1 year.
(C) increased complications in the central lung tumors.
(D) an improved abscopal effect by reducing distant metastases.

Key: B
Solution: RTOG 0915 enrolled medically inoperable patients with peripheral stage I non-small cell lung cancers only. 34 Gy in one fraction demonstrated similar primary tumor control and protocol-specified adverse events as 48 Gy in 4 fractions. This study was designed expecting to have similar local control while the arm with the least side effects was to be compared to 54 Gy in 3 fractions from RTOG 0236. The primary tumor control rates were 97% in the single fraction arm vs 92.7% in the four-fraction arm.

154. Regarding RTOG 0617 for lung cancer, what were the per protocol constraints for total lungs minus CTV?

(A) V20 ≤ 25% and mean dose ≤ 15 Gy
(B) V20 ≤ 25% and mean dose ≤ 20 Gy
(C) V20 ≤ 37% or mean dose ≤ 15 Gy
(D) V20 ≤ 37% or mean dose ≤ 20 Gy

Key: D

Solution: The per protocol lung constraint in RTOG 0617 was for total (bilateral) lungs minus CTV. The recommended constraints were V20 ≤ 37% or alternatively a mean dose ≤ 20 Gy.

https://www.rtog.org/ClinicalTrials/ProtocolTable/StudyDetails.aspx?study=0617


155. In the management of brain metastases in RTOG 0933, reducing hippocampus dose was associated with:

(A) an increase in grade 3 or higher morbidity.
(B) a lack of decline in short term memory at 4 months.
(C) a substantial increase in failures in the hippocampus.
(D) an improvement in quality of life related to reduced alopecia.

Key: B

Solution: The RTOG 0933 was a single-arm phase II study of hippocampal avoidance whole brain radiotherapy (WBRT) for brain metastases with prespecified comparison with a historical control of patients treated with WBRT without hippocampal avoidance. Eligible adult patients with brain metastases received HA-WBRT to 30 Gy in 10 fractions. Standardized cognitive function and quality-of-life (QOL) assessments were performed at baseline and 2, 4, and 6 months. The primary end point was the Hopkins Verbal Learning Test-Revised Delayed Recall (HVLT-R DR) at 4 months. The historical control demonstrated a 30% mean relative decline in HVLT-R DR from baseline to 4 months. To detect a mean relative decline ≤ 15% in HVLT-R DR after HA-WBRT, 51 analyzable patients were required to ensure 80% statistical power with α = 0.05. Of 113 patients accrued from March 2011 through November 2012, 42 patients were analyzable at 4 months. Mean relative decline in HVLT-R DR from baseline to 4 months was 7.0% (95% CI, -4.7% to 18.7%).


156. Following surgery for a large cell carcinoma of the left lung, pathology demonstrated a 2.5 cm primary cancer with negative margins where there were four involved level 11 lymph nodes and 1 AP window lymph node that demonstrated metastatic disease. What is the recommended treatment following surgery?

(A) Cisplatin based doublet x 4 cycles 
(B) Mediastinal RT followed by cisplatin based doublet x 4 cycles 
(C) Cisplatin based doublet x 4 cycles followed by mediastinal RT 
(D) Concurrent chemoRT to the mediastinum with carboplatin + paclitaxel

**Key:** C

**Solution:** For patients with pathologic stage IIIA disease which is evidence by the AP window lymph node, mediastinal radiation is recommended (NCCN guidelines) based on an abundance of data based on large national registries (SEER- Lally, and Robinson -NCDB). Although concurrent chemotherapy has been shown to be safe and effective, it has not been show to improve survival n the adjuvant setting. The preference is to follow the sequential approach based on the large European Trials (Douillard).


157. What was the radiation dose on the experimental arm of the CONVERT trial presented at the 2016 ASCO that used 45 Gy (1.5 Gy twice daily) as the standard arm for limited stage SCLC?

(A) 45 Gy 
(B) 60 Gy 
(C) 66 Gy 
(D) 70 Gy

**Key:** C

**Solution:** CONVERT trial is an international randomized trial of concurrent chemo-radiotherapy comparing twice daily (45 Gy) and daily (66 Gy) radiotherapy schedules in patients with limited-stage SCLC and good performance status. Results were presented at the 2016 ASCO meeting showing a 2-yr OS of 56% vs 51% and median OS of 30m vs 25 m (p=0.15) with no differences in toxicity supporting the use of either regiment for standard of care treatment of LS-SCLC with good PS. The standard-arm in Turrissi, et al. Trial was 45 Gy daily. CALGB 30610 is an ongoing trial comparing 45 Gy BID vs 70 Gy OD (61.2 Gy concomitant boost arm was closed early).

**References:** Journal of Clinical Oncology. 2016; Supp; abstr 8504.
158. In patients with early-stage NSCLC planned for surgical resection:
(A) a minimum of 3 N2 stations should be sampled.
(B) LRC rates with sub-lobar or lobar resection are similar.
(C) complete mediastinal nodal dissection improves survival over sampling.
(D) nodal stations 4, 5, 6, 7, 8 and 9 should be sampled for right-sided tumors.

Key: A
Solution: In a randomized phase-III trial by LCSG, sub-lobar resection resulted in a 75% increase in relative recurrence rates versus lobar resection (Ginsberg et al). In a randomized trial (ACOSOG Z0030), no added benefit of completion mediastinal nodal dissection if thorough nodal sampling was negative. For right sided tumors 2R, 4R, 7 and 10R were sampled, while for left-sided lesions 5, 6, 7 and 10L were sampled. To improve predictive probability of sampling, NCCN also suggests stations 8 and 9 sampling with a minimum of 3 N2 stations to be sampled. Knowledge of adequate surgical management can guide adjuvant therapy.

159. In RTOG 0617 for patients with unresectable NSCLC who were treated with definitive chemoRT, which factor was significantly associated with OS on multivariate analysis?
(A) Heart V30
(B) RT protocol compliance
(C) RT technique (3DCRT vs IMRT)
(D) Systemic chemotherapy dose compliance

Key: A
Solution: On multivariate analyses, factors predicting overall survival in RTOG 0617 were radiation dose (60 Gy), maximum esophagitis grade, planning target volume, and heart V5 and V30. Radiation therapy and chemotherapy compliance, and radiation therapy technique were not significant for overall survival in these analyses, however IMRT did reduce pneumonitis rates.

160. What is the mechanism of action for nivolumab?
(A) Anti-angiogenic agent
(B) Anti-PD-1 receptor antibody
(C) BRAF V600E kinase inhibitor
(D) Receptor tyrosine kinase inhibitor

Key: B
Solution: Nivolumab is a humanized monoclonal antibody that binds to the PD-1 receptor and blocks its interaction with PD-L1 and PD-L2. It was recently approved by FDA to treat patients with advanced NSCLC refractory to first line platinum-based chemotherapy. In a phase-III trial (CHECKMATE 057), use of nivolumab was associated with improved survival (1-yr OS 51% vs 39%, median survival 12.2 m vs 9.4 m, p = 0.002) when compared to single agent docetaxel, regardless of PD-L1 status.
161. In the Auperin meta-analysis of limited stage SCLC patients, PCI reduced the 3-year incidence of brain metastases from 58.6% to:
   (A) 13%.
   (B) 23%.
   (C) 33%.
   (D) 43%.

**Key:** C

**Solution:** The findings from individual-patient data meta-analysis of patients with SCLC in CR treated with or without PCI showed improvement in 3-year survival from 15.3% to 20.7% and reduced incidence of brain metastases from 58.6% to 33.3%, a 25% absolute difference in brain metastases.


162. Regarding surgical planning for patients with thymoma:
   (A) pericardial involvement is a contraindication for surgery.
   (B) maximal debulking should be aimed in unresectable patients.
   (C) CT-guided trans-pleural biopsy is recommended prior to surgery.
   (D) serum anti-acetylcholine receptor antibody levels should be obtained pre-surgery.

**Key:** D

**Solution:** Approximately 30-50% of patients with thymomas have myasthenia gravis. Hence, before any surgical procedure, all patients suspected of having thymomas should have their serum antiacetylcholine receptor antibody levels measured. Surgical biopsy is not necessary if a resectable thymoma is strongly suspected clinic-radiologically. If biopsy is performed, a transpleural approach is avoided to prevent tumor seeding. Unresectable patients are treated with induction therapy followed by re-assessment for surgery. Pericardial resection with graft reconstruction is attempted when feasible.

**References:** NCCN guidelines 2016.

163. Based on a large multi institutional experience treating patients with concurrent chemoRT for advanced NSCLC (Palma), which dosimetric factor BEST predicted grade 2 or higher esophagitis?
   (A) V20 of the Esophagus
   (B) V30 of the Esophagus
   (C) V60 of the Esophagus
   (D) Mean Dose to the Esophagus

**Key:** C

**Solution:** Esophagitis is the primary side effect that occurs during radiotherapy and this article is the 1st large data set to evaluate multiple variables is a multi-institutional setting. They systematically evaluated DVH of the esophagus from V5 through V70 by 5 Gy increments as well as the mean, max dose total dose and fractionation. The best model was found to be in the high dose volumes such as V50 and V60 which predicted both grade 2 and 3 events.

164. A 75-year-old presented with weight loss, progressive shortness of breath, and recent onset of delirium. Workup shows a large mediastinal mass and a sodium level of 116 mEq*/L. What is the next step in management?
(A) Brain MRI
(B) FDG-PET/CT
(C) Hypertonic saline
(D) Bronchoscopy and biopsy

Key: C
Solution: Patients with SIADH and acute onset of symptomatic hyponatremia should be managed with slow infusion of hypertonic saline and not to exceed a correction of 1 to 2 nmol per L per hour. All other choices are not appropriate for the acute management of the patient’s hyponatremia which is the result of SIADH, likely related to small cell lung cancer.

165. Regarding the randomized trial investigating the role of thoracic RT for extensive-stage SCLC (Slotman), the addition of thoracic RT:
(A) improved the 2-year OS.
(B) did not improve 6 month PFS.
(C) consisted of 45 Gy in 30 Fx over 3 weeks.
(D) significantly increased Grade 3 or higher toxicity.

Key: A
Solution: In this study patients with extensive stage small cell lung cancer that had a response to chemotherapy were randomized to receive thoracic radiation therapy (30 Gy in 10 fractions) or no thoracic radiation therapy. All patients received prophylactic cranial irradiation (PCI). The primary endpoint was 1 year overall survival which was similar between the two groups (33% vs 28%, p=0.066), however a post-hoc secondary analysis revealed significantly greater 2-year overall survival in the thoracic radiation therapy group (13% vs 3%, p=0.004). Six-month progression-free survival was significantly improved in the thoracic radiation group (24% vs 7%, p=0.001). Grade 3 or higher toxicity was similar between the two groups (26 patients vs 18 patients, p=0.28)

166. Which chemotherapy has been shown to improve OS when combined with Cisplatin for patients with malignant pleural mesothelioma?
(A) Paclitaxel
(B) Vinorelbine
(C) Pemetrexed
(D) Gemcitabine

Key: C
Solution: The addition of pemetrexed at 500 mg/m2 to 75 mg/m2 of cisplatin every 21 days improved median overall survival (12.1 months vs 9.3 months), median time to progression (5.7 months vs 3.9 months) and improved response rates (41% vs 17%) compared to cisplatin alone.
167. Based on level 1 evidence, what would be recommended following a completely resected 5.1 cm intermediate grade adenocarcinoma without evidence of lymphadenopathy?

(A) Observation
(B) Sequential postoperative chemoRT
(C) Discuss the role of adjuvant chemotherapy
(D) Adjuvant chemotherapy using a cisplatin based doublet

Key: C
Solution: In CALGB 9633 in patients with stage IB (T2N0) that are completely resected were randomized to adjuvant chemo vs. not, and the trial was negative for the benefit of adjuvant chemo except for the large tumors >=4.0 cm in an unplanned subset analysis. In the subset of patients with larger tumors, they found an improvement in OS with the use of adjuvant chemo. While not level 1 evidence, this suggests a possible consideration for the role of adjuvant chemotherapy, which needs to be discussed with the patient.


168. What is the BEST treatment approach for a T3N0 malignant epithelioid mesothelioma?

(A) Platinum-based chemotherapy
(B) Extrapleural pneumonectomy alone
(C) Platinum-based chemotherapy, followed by concurrent chemoRT
(D) Induction chemotherapy, pleurectomy and decortication, followed by IMRT

Key: D
Solution: Andreas Rimner at MSKCC in a multicentre phase II study recently published in the JCO that induction chemo, decortication and pleural-based IMRT is an excellent option for patients without compromised (if not better) survival than patients treated historically with EPP and radiation therapy.


169. What is the minimum biologically effective dose (Gy10) to achieve a LC rate of at least 90% for SBRT in early stage NSCLC?

(A) 75
(B) 100
(C) 125
(D) 150

Key: B
Solution: Zhang et al. explored the optimal biological effective dose (BED) range for the treatment of patients with Stage I non-small cell lung cancer with Stereotactic Body Radiation Therapy (SBRT). According to the quartile of the studies included into this meta-analysis, BED was divided into four dose groups: low (<83.2 Gy), medium (83.2-106 Gy), medium to high (106-146 Gy), high (>146 Gy). Corrected 3-year CSS in the medium (79.5%), medium to high (80.6%), and high groups (90.0%) were higher than in the low group (70.1%, p = 0.016, 0.018, 0.001, respectively). The biological effective dose (BED10) used for SABR treatment should be at least 100 Gy (grade B recommendation). The biological effective dose (BED10) used for SABR treatment should be at least 100 Gy (grade B recommendation).

170. What is the T stage (AJCC 7th Ed) for a patient with Mycosis Fungoides that has one or more tumors (≥ 1 cm in diameter)?
   (A) T1  
   (B) T2  
   (C) T3  
   (D) T4  

Key: C

Solution: T1-limited patches, plaques < 10% of skin surface; T2- Patches, plaques covering ≥ 10% of skin surface; T3- one or more tumors (≥1cm in diameter) T4- confluence of erythema ≥ 80% body surface area;


171. What radiation dose is considered the standard of care based on findings from the FORT randomized phase 3 non-inferiority trial for indolent follicular and marginal zone lymphoma?
   (A) 4 Gy in 2 Fx  
   (B) 10 Gy in 5 Fx  
   (C) 12 Gy in 6 Fx  
   (D) 24 Gy in 12 Fx  

Key: D

Solution: This trial compared 4 Gy in 2 fractions vs 24 Gy in 12 fractions for patients> 18 y/o needing radiotherapy for marginal zone or follicular lymphoma; The findings were that 24 Gy in 12 fractions is the more effective radiation dose and should be considered as standard of care;


172. Which is considered a sanctuary site for consideration in TBI-based transplant preparative regimens?
   (A) Liver  
   (B) Lungs  
   (C) Testes  
   (D) Kidneys  

Key: C

Solution: TBI does not spare sanctuary sites such as testes and CNS. As a matter of fact, when such sites are involved with disease, one is more likely to use TBI based regimen and/or boost these sanctuary sites to try and eradicate disease within these sanctuary sites; All of the other are unique features of TBI, which makes is it an attractive conditioning regimen.

References: Wolden SL; Rabinovitch RA; Bittner NH, American College of Radiology (ACR) and American Society for Radiation Oncology (ASTRO) practice guideline for the performance of total body irradiation (TBI), (2013) 36(1).
173. Which of the following expression profiles is consistent with nodular lymphocyte predominant Hodgkin lymphoma?
   (A) CD15-,CD30-,CD20-,CD45-
   (B) CD15+,CD30+,CD20-,CD45-
   (C) CD15-,CD30-,CD20+,CD45+
   (D) CD15+,CD30+,CD20+,CD45+

   **Key:** C

   **Solution:** Unlike classical Hodgkin’s lymphoma, which expresses CD15 and CD30 but does not express CD20 and CD45, nodular lymphocyte predominant Hodgkin’s lymphoma does not express CD15 and CD30 but consistently expresses both CD20 and CD45.


174. The rationale for proton therapy versus conventional photon therapy in Hodgkin disease is to:
   (A) decrease treatment time.
   (B) escalate dose above 45 Gy.
   (C) minimize late adverse effects.
   (D) minimize acute adverse effects.

   **Key:** C

   **Solution:** Proton therapy lacks exit dose and therefore delivers less dose to normal tissues than photon therapy, particularly in the low and intermediate dose ranges. Early clinical data demonstrate that proton therapy leads to acute toxicity and disease outcomes similar to those expected from photon therapy. The strongest rationale for using proton therapy in Hodgkin disease patients is the reduction in clinically significant late adverse effects, especially since many Hodgkin disease patients are treated at a young age will live for many decades after being cured.


175. What is the MOST common site of involvement in mucosa-associated lymphoid tissue (MALT) lymphomas?
   (A) Skin
   (B) Orbit
   (C) Stomach
   (D) Waldeyer’s ring

   **Key:** C

   **Solution:** The most common site of involvement of MALT is GI tract, of which 80-90% occur in stomach. Other non-gastric sites such as orbit, lung and skin are involved in approximately 10% cases.

176. According to the UK RAPID Trial, patients with favorable early stage Hodgkin lymphoma who receive 3 cycles of ABVD chemotherapy:

(A) require 1 more cycle of ABVD if a PET/CT scan response was a Deauville 2
(B) receive escalated BEACOPP x 4 if a PET/CT scan response was a Deauville 4
(C) require 1 more cycle of ABVD followed by RT if PET/CT response was a Deauville 4
(D) can omit radiation without compromising efficacy if PET/CT scan response was a Deauville 3

Key: A&C

NOTE: This item was multi-keyed for scoring purposes upon post-exam statistical item analysis (Both A and C were given credit as correct responses).

Solution: B is incorrect, Deauville 2 was the cut off. C is incorrect, these patients didn’t need more chemo or RT, D is wrong, they just got 1 more cycle of ABVD and then RT.

References: Radford, Illidge, Counsell. 2015. Results of a Trial of PET-Directed Therapy for Early-Stage Hodgkin’s Lymphoma. NEJM 372; 1598-1607.

177. In a 22-year-old female with stage IIA bulky Hodgkin Lymphoma, who receives ABVD followed by cervical and mediastinal RT to 30 Gy, what is the appropriate assessment for late effects from treatment?

(A) Cardiac CT scan performed annually
(B) Serum lipid profile tests done every 10 years
(C) Serum thyroid function tests performed annually
(D) Breast screening starting 3 years following completion of treatment

Key: C

Solution: A is wrong, should start 8-10 years following treatment. C is wrong, it should be done annually or biannually starting 5 years post treatment. D is wrong, no role for cardiac CT at this time. It exposes patients to a lot of radiation.


178. Ibritumomab tiuxetan (Zevalin®) is a monoclonal antibody for which cell surface receptor?

(A) CD3
(B) CD15
(C) CD20
(D) CD30

Key: C

Solution: Ibritumomab tiuxetan (Zevalin) consists of a CD20-specific monoclonal antibody that is conjugated to yttrium-90. Indications include consolidation after induction therapy for follicular lymphoma, as monotherapy in the first-line treatment of follicular lymphoma, as well as for relapsed or refractory follicular lymphoma.

179. Per-protocol analysis of RICOVER-60 and RICOVER-noRTh data for DLBCL patients receiving RT demonstrated:
(A) improvement in EFS was seen only in patients with bulky disease.
(B) only EFS benefit was seen for patients > 60 years with bulky disease.
(C) improvement in both PFS and OS was seen only in younger patients.
(D) improvement in both PFS and OS seen for patients > 60 years with bulky disease.

Key: D
Solution: Post-hoc analysis of data from prospective RICOVER-60 trial and the amendment cohort receiving same chemoimmunotherapy with no RT for elderly patients (age > 60 years) with bulky disease (≥7.5 cm) (RICOVER-noRTh), use of RT (36 Gy) was associated with improved EFS, PFS and OS. This data does not evaluate the question regarding role of RT based on PET-complete remission. Mature data from German High-Grade NHL Study Group sponsored UNFOLDER trial (NCT00278408) are awaited. Preliminary data shows improved EFS with the use of RT in all patients with bulky disease or extranodal sites.


180. Which classical Hodgkin lymphoma subtype has the worst prognosis?
(A) Lymphocyte rich
(B) Nodular sclerosis
(C) Mixed cellularity
(D) Lymphocyte depleted

Key: D
Solution: Klimm et al. reviewed 12,155 Hodgkin’s lymphoma patients treated within the German Hodgkin Study Group trials HD4 to HD15 and demonstrated that patients with the lymphocyte depleted subtype had the lowest 5-year progression-free survival and overall survival compared to other subtypes.


181. Regarding solitary plasmacytomas:
(A) RT dose is 20-30 Gy.
(B) requires bone marrow plasma cells > 10%.
(C) bone is more common than extra-medullary.
(D) Extramedullary is more likely to progress to multiple myeloma.

Key: C
Solution: Approximately 2/3rd of solitary plasmacytomas arise in bone and 1/3rd are extramedullary. Bone plasmacytomas are more likely to transform to myeloma. A wide range of RT dose have been described. NCCN recommends a dose > 30 Gy for solitary bone or extramedullary plasmacytoma. Diagnosis of solitary plasmacytoma requires normal bone marrow plasma cells (< 10%). Elevated plasma cells without end-organ damage is a criterion for Smoldering multiple myeloma.

182. The main dose-limiting toxicity of TBI involves which organ?
   (A) Skin
   (B) Lung
   (C) Heart
   (D) Bowel

   Key: B
   Solution: Total body irradiation can cause adverse effects involving the skin, lung, heart, and bowel. However, the most clinically significant toxicities involve the lungs. Pulmonary complications may present acutely as pneumonitis or later as pulmonary fibrosis. Pulmonary complications are reported in 30-60% of all recipients, and is a major cause of mortality.

183. Which criterion is included in the definition of symptomatic Myeloma?
   (A) Calcium < 11.5 mg/dL
   (B) Creatinine < 2 mg/dL
   (C) Hemoglobin > 10 g/dL
   (D) Multiple lytic bone disease

   Key: D
   Solution: “CRAB” criteria used to determine symptomatic myeloma: C-Elevated Calcium (>11.5 mg/dL), R-Renal Insufficiency (Cr > 2 mg/dL), A-Anemia (<10 g/dL), Bone-lytic/osteopenic lesions.

184. The minimum size cut-off in axial dimensions to define bulky disease for DLBCL as used in recent clinical trials, such as the RICOVER-60, UNFOLDER trials and also adapted by the NCCN guidelines v3.2016, is:
   (A) 5 cm.
   (B) 7.5 cm.
   (C) 10 cm.
   (D) 12 cm.

   Key: B
   Solution: The definition of bulky disease has evolved from use of X-ray based definitions of maximum “Mass to Thoracic Ratio” >33% to CT scan based definition of the above ratio at T5-6 vertebral level of > 0.35, or nodal mass with maximal dimension >10cm. Recent clinical trials use a cut-off of ≥ 7.5 cm, which was also adapted in the NCCN guidelines.
185. What dose per fraction (Gy) should be used for palliative splenic RT for CLL?
   (A) ≤1
   (B) 2
   (C) 3
   (D) 4

**Key:** A  
**Solution:** Palliative splenic radiation therapy is typically given to the whole spleen in 0.25-1 Gy fractions delivered daily or 2-3 times per week to a total dose of 4-10 Gy. This is to minimize the risk of significant hematologic toxicity; blood counts should be monitored several times each week.  

186. Patients with mycosis fungoides who receive total body skin electron therapy should receive a boost to which of the following regions?
   (A) Knees
   (B) Perineum
   (C) Anterior neck
   (D) Palms of the hands

**Key:** B  
**Solution:** Areas that may be underdosed including the scalp, axillae, perineum, and soles of the feet should be boosted.  

187. A patient with bulky stage II Diffuse large B cell lymphoma has a Deauville 4 response on PET/CT following 6 cycles of RCHOP. This response is consistent with:
   (A) a complete response.
   (B) greater than the liver but less than the mediastinum.
   (C) less than the liver but greater than the mediastinum.
   (D) moderately greater than the liver and mediastinum.

**Key:** D  
**Solution:** 5 point Deauville scale: 1 no uptake. 2 background uptake <= mediastinum. 3 uptake > mediastinum, but less than liver. 4 moderate uptake greater than mediastinum and liver. 5 marked uptake higher than liver and mediastinum and/ or new areas of PET uptake.  
188. The Follicular Lymphoma International prognostic index (FLIPI) includes:
   (A) age (≥45 vs <45).
   (B) ESR (≥20 vs <20).
   (C) hgb (≥8 vs <8).
   (D) nodal areas (≥4 vs ≤4).

Key: D
Solution: See reference describing factors involved.

189. Regarding the revised international staging system for multiple myeloma, Serum beta-2 microglobulin < 3.5, Serum Albumin ≥ 3.5 dL and standard risk chromosomal abnormalities by FISH and serum LDH < upper limit of normal constitutes which stage?
   (A) 0
   (B) I
   (C) II
   (D) III

Key: B
Solution: The revised ISS stage I for myeloma now includes the following (Serum beta-2 microglobulin < 3.5, Serum Albumin ≥ 3.5 dL and standard risk chromosomal abnormalities by FISH and serum LDH < upper limit of normal); The 5 yr OS rate for R-ISS stage 1 is 82%; Serum beta-2 microglobulin ≥ 5.5 mg/L would make it stage 2 or 3, depending on presence or absence of high risk chromosomal abnormalities and/or elevated LDH.

190. Which of the following parameters is an adverse prognostic factor per the DLBCL International Prognostic Index (IPI)?
   (A) Stage II
   (B) Age > 50 years
   (C) Elevated serum LDH
   (D) Any extranodal involvement

Key: C
Solution: Factors accounting for higher IPI score (adverse prognosis) include Age > 60 years, Elevated LDH, Performance status ≥ 2, Stage III/IV, > 1Extranodal site involvement. Bulky disease, though an adverse factor is not included in IPI. An updated analysis in the rituximab era (NCCN-IPI) further refines above criteria and better stratifies patients into four risk groups with 5-year survival of 96%, 82%, 64% and 33% respectively.
191. What is the radiation treatment of a Wilms tumor of the left kidney with positive margins, no anaplasia, no spill, negative lymph nodes and no metastases?
   (A) No RT
   (B) Left flank radiation to 10.8 Gy
   (C) Left flank radiation to 19.8 Gy
   (D) Whole abdominal radiation to 10.5 Gy

Key: B
Solution: The positive margin in the setting of no metastases is stage III by COG staging. The patient should receive left flank radiation to a dose of 10.8 Gy in 1.8Gy fractions.

192. Which is a special consideration in designing whole brain fields for pediatric leukemia patients requiring cranial radiation?
   (A) Ensure that the cochleae are blocked
   (B) Fields designed to block the cribiform plate
   (C) Ensure that dose covers the posterior globes
   (D) Inferior border of the field is at the level of C3/C4

Key: C
Solution: The inferior border of the field is placed at the lower border of C2. The cribiform plate should be included in the field and a contour of this structure aids in drawing blocks correctly. Due to the risk of disease in the retina, standard convention includes treatment of the posterior globe and orbit.

193. Regarding delivery of whole abdominal radiation for patients with Wilms tumor:
   (A) the dose per fraction is 1.8 Gy.
   (B) the superior border is 1 cm above the most superior extent of the renal tumor.
   (C) only flank irradiation is indicated for preoperative intraperitoneal tumor rupture.
   (D) the inferior border of the whole abdomen field is the bottom of the obturator foramen.

Key: D
Solution: Dose per fraction for whole abdominal radiation is 1.5Gy. The superior border is defined superiorly by the diaphragm. Whole abdominal radiation is indicated for both diffuse tumor spill and preoperative intraperitoneal rupture.
194. What is the MOST common chromosomal translocation in Ewing's sarcoma?

(A) t(14;18)
(B) t(11;14)
(C) t(11;22)
(D) t(21;22)

Key: C
Solution: t(11;22) is found in 86 – 90% of Ewing’s sarcomas. t(21;22) is found in 5 – 10% of Ewing’s sarcomas. t(14;18) is found in follicular B-cell lymphoma. t(11;14) is found in mantle cell lymphoma.

195. Which molecular subgroup of medulloblastoma has the highest 5 year OS?

(A) Group 3
(B) Group 4
(C) WNT pathway
(D) SHH pathway

Key: C
Solution: The WNT pathway is involved in 10% of medulloblastomas and has a 5 year OS of 95%. SHH, Group 3, and Group 4 medulloblastomas have 5 y OS of 75%, 50%, and 75%.

196. Sporadic cases of retinoblastoma are:

(A) most often bilateral.
(B) less frequent than familial cases.
(C) due to mutation of the RB1 oncogene.
(D) due to somatic mutation of both RB1 genes.

Key: D
Solution: Most cases of retinoblastoma are sporadic whereas 25-40% are familial. Familial retinoblastoma is more often bilateral and occurs at a younger age. The development of retinoblastoma is due to inactivation of the tumor suppressor gene RB1. In cases of familial retinoblastoma a gamete with a defective RB1 gene (the first hit) leads to a heterozygous zygote and a later somatic mutation in the other RB1 gene (the second hit) leads to the formation of tumors. In sporadic retinoblastoma inactivating somatic mutations in both RB1 genes (two hits) leads to the development of tumors.
197. On the Intergroup Rhabdomyosarcoma Study IV, the 3 year FFS of patients with metastatic embryonal rhabdomyosarcoma involving 2 or fewer metastatic sites was:

(A) 10%.
(B) 25%.
(C) 40%.
(D) 65%.

**Key:** C

**Solution:** On this trial, the 3 year FFS for patients with embryonal RMS and up to 2 metastatic sites was 40%. 3 year FFS for patients with embryonal RMS and 3 or more metastatic sites was 25%. 3 year FFS for patients with non-embryonal RMS and up to 2 metastatic sites was 21%. 3 year FFS for patients with non-embryonal RMS and 3 or more metastatic sites was 5%.


198. What is the most appropriate radiation target volume for treatment of a 4-year-old boy with a localized anaplastic ependymoma of the posterior fossa with 2 cc of residual tumor?

(A) Residual tumor
(B) Craniospinal axis
(C) Entire posterior fossa
(D) Residual tumor and tumor bed

**Key:** D

**Solution:** Ependymoma tends to fail locally. Even for anaplastic tumors, local fields encompassing residual tumor and the tumor bed are most appropriate for patients without dissemination in the neuroaxis.


199. Regarding late effects of treatment for childhood retinoblastoma:

(A) the risk of cataract formation after external beam radiation is < 10%.
(B) the most common secondary malignancy in the radiation field is Ewing sarcoma.
(C) survivors of bilateral retinoblastoma have a 25 – 30% risk of secondary malignancy at 30 years.
(D) survivors of bilateral retinoblastoma treated with surgery and chemotherapy alone have a low risk of secondary malignancy.

**Key:** C

**Solution:** The risk of secondary malignancy is survivors of bilateral retinoblastoma is 25-30% and reported as high as 50% at 50 years. The most common secondary malignancy in the radiation field is osteosarcoma. Although radiation therapy increases the risk of secondary malignancy, survivors of bilateral retinoblastoma treated without radiation therapy also have a significantly increased risk of a second malignancy. Even with a lens sparing beam arrangement, the risk of cataract formation is greater than 10% and with an anterior beam design the risk approaches 90%.

200. Which of the following characteristics is considered stage II Wilms tumor?
   (A) Preoperative tumor rupture
   (B) Tumor within the renal sinus
   (C) Positive lymph node involvement
   (D) Tumor is removed in greater than one piece (piecemeal resection)

Key: B
Solution: Tumor within the renal sinus is considered Stage II disease. Factors considered stage III disease include spillage, lymph node involvement, unresected disease, rupture of tumor, positive margins, piecemeal resection, peritoneal disease and biopsy (SLURPPP-Bx).

201. What is the MOST common secondary malignancy after radiation for Ewing’s sarcoma?
   (A) Sarcoma
   (B) Leukemia
   (C) Meningioma
   (D) Thyroid carcinoma

Key: A
Solution: Sarcomas are the most common secondary malignancy after radiation for Ewing’s sarcoma; other secondary malignancies include leukemia, meningiomas, and carcinomas.

202. In high risk neuroblastoma, radiation therapy should be delivered:
   (A) after induction chemotherapy.
   (B) within 10 days after biopsy of the primary lesion.
   (C) within 10 days after resection of the primary lesion.
   (D) within 4-6 weeks after autologous stem cell transplant.

Key: D
Solution: High risk neuroblastoma patients are typically treated in three phases: Induction, including induction chemotherapy followed by primary tumor resection; Consolidation, including myeloablative chemotherapy with autologous stem cell transplant and consolidative radiation; and post-consolidation immunotherapy and cytokines plus isotretinoin.
203. What characterizes CNS 1 disease in pediatric acute lymphoblastic leukemia (ALL)?
   (A) No evidence of blasts in the CSF
   (B) CSF WBC count of < 5 cells/µL with blasts present
   (C) CSF WBC count of ≥ 5 cells/µL with blasts present
   (D) Clinical signs of CNS leukemia such as facial nerve palsy

Key: A
Solution: CNS 3 leukemia is a CSF WBC count of ≥ 5 cells/µL with blasts present or clinical signs of CNS involvement. CNS 2 disease is a CSF WBC count of < 5 cells/µL with blasts present. CNS 1 disease is no evidence of blasts in the spinal fluid.

204. What is the GTV for adjuvant radiation of a 3-year-old boy with an N-myc amplified, high risk right adrenal neuroblastoma after biopsy, induction chemotherapy, and near gross total resection?
   (A) The extent of residual disease after resection
   (B) The extent of disease at biopsy, before induction chemotherapy
   (C) The extent of disease at resection, after induction chemotherapy
   (D) None, because the patient does not require adjuvant radiation therapy

Key: C
Solution: Adjuvant radiation therapy is required for patients undergoing treatment for high risk neuroblastoma. The gross tumor volume is the extent of disease at the time of resection, whether that occurs prior to chemotherapy or after induction chemotherapy. Because neuroblastoma is often sensitive to chemotherapy, it is usually preferable that resection occur after induction chemotherapy to minimize the target volume.

205. What is the MOST common tumor of the pineal region in children and adolescents?
   (A) Germinoma
   (B) Astrocytoma
   (C) Pineoblastoma
   (D) Non-germinomatous germ cell tumors

Key: A
Solution: Germinomas account for 40 – 60% of pineal region tumors. NGGCT account for 20 – 25% of these tumors. Pineal parenchymal tumors including pineoblastomas are about 14%. Gliomas, astrocytomas, and ependymomas account for about 15%.
206. What is the radiation dose for a pediatric patient with a 4 cm rhabdomyosarcoma of the right neck with a partial response to induction chemotherapy?
   (A) 36 Gy in 20 Fx
   (B) 45 Gy in 25 Fx
   (C) 50.4 Gy in 28 Fx
   (D) 59.4 Gy in 33 Fx

**Key:** C  
**Solution:** This patient has group III disease because there was gross disease at the start of chemotherapy. Conventional radiation therapy dose to Group III disease is 50.4 Gy in 28 fractions.  

207. What was the MINIMUM criterion for patient classification as a “rapid early responder” according to COG protocol AHOD 0031 for intermediate risk Hodgkin Disease?
   (A) PET negative after 4 cycles of chemotherapy
   (B) Gallium negative after 4 cycles of chemotherapy
   (C) Decrease of short axis dimension by at least 70% in up 5 areas of disease after 2 cycles of chemotherapy
   (D) Decrease in products of perpendicular diameters of at least 60% of up to 6 largest areas of disease after 2 cycles of chemotherapy

**Key:** B  
**Solution:** On this trial, initial response was assessed after 2 cycles of ABVE-PC. Patients with a rapid early response were classified as having met the criteria for a very good partial response including a decrease in products of perpendicular diameters of at least 60 percent (or return to normal size) of up to 6 largest areas. Patients who met that criteria, and then met the protocol’s guidelines for a complete response after 2 additional cycles of ABVE-PC were randomized to observation or involved field radiation. Other patients received involved field radiation (except patients with progressive disease who came off protocol).  
208. On AHOD 0031, a COG study of patients with intermediate risk Hodgkin disease, recurrences rarely occurred:
(A) in new sites of disease.
(B) concurrently in new sites of disease and original sites of disease.
(C) in original sites of disease.
(D) non-bulky sites of disease.

Key: A
Solution: This study showed that pediatric patients achieving rapid early response after 2 cycles of chemotherapy and complete response after 4 cycles of chemotherapy did not require adjuvant radiation therapy. However, when patients had recurrences of their disease, it was very frequently in the adjuvant involved field radiation volumes. 21 Gy of involved field radiation did not improve outcome for slow early responding patients.


209. What is the appropriate radiation volume and dose for a child with a right sided stage III Wilms tumor with positive lymph nodes, no spill, and no rupture with diffuse anaplasia?
(A) Right flank radiation; 10.8 Gy
(B) Right flank radiation; 19.8 Gy
(C) Whole abdominal radiation; 19.8 Gy
(D) Right flank radiation; 36 Gy

Key: B
Solution: Stage III diffuse anaplasia requires a dose of 19.8 Gy.


210. Which hormone is most likely to be deficient after a hypothalamic dose of 18 Gy in a child?
(A) Growth hormone
(B) Luteinizing hormone
(C) Adrenocorticotrophic hormone
(D) Thyroid stimulating hormone

Key: A
Solution: Growth hormone deficiency occurs at hypothalamic doses of at least 18 Gy. Deficiencies of the other hormones develop at higher hypothalamic doses.

211. According to the COG, what is the stage of a 6 cm non-parameningeal head and neck embryonal rhabdomyosarcoma without nodal or distant metastases?

(A) 1  
(B) 2  
(C) 3  
(D) 4  

Key: A  
Solution: COG rhabdomyosarcoma staging is by risk of site, nodal status, metastases, tumor invasiveness and size. Non-parameningeal head and neck patients without metastatic disease have Stage 1 disease, regardless of size of tumor, invasiveness, or draining lymph node involvement.  

212. How does radiation affect spermatogenesis?

(A) Radiation sensitivity increases as sperm mature  
(B) Spermatogenesis is more sensitive to fractionated doses  
(C) Onset of azoospermia occurs more rapidly with lower doses  
(D) Recovery of spermatogenesis is dose-dependent and takes approximately 1-2 weeks  

Key: B  
Solution: Dependent on location in maturation pathway, radiation sensitivity decreases as sperm mature. Recovery of spermatogenesis is dose-dependent and takes between 1-5 years. Onset of azoospermia occurs more rapidly with higher doses.  

213. The duration of which phase of the cell cycle is most variable?

(A) G1  
(B) G2  
(C) M  
(D) S  

Key: A  
Solution: Length in G1 can vary from less than an hour to more than a week.  
214. What is an advantage of proton therapy over photon therapy for pediatric CSI?

(A) Increased RBE of protons enhances tumor control
(B) Less neurotoxicity for a given biologically equivalent dose
(C) Reducing radiation dose to anterior structures including the heart
(D) Reduced exposure to the kidneys due to sharper penumbra of proton beam

**Key:** C

**Solution:** The correct answer is B. For medulloblastoma the entire brain and spine are treated. For treatment of the spine, in contrast to photon therapy, proton therapy eliminates exit dose to anterior structures such as the heart. This reduction in dose is expected to reduce the incidence of radiation induced cardiac disease. For proton therapy, the RBE is 1.1 in comparison to photons. This is accounted for during treatment planning and hence the effective doses for either modality are expected to be similar.

**References:** Merchant Semin Radiat Oncol. 2013 Apr; 23(2):97-108.

215. What is one rationale for inclusion of concurrent bevacizumab with re-irradiation of recurrent glioblastoma?

(A) Treatment of radiation necrosis
(B) Alters MGMT methylation status
(C) Reduces HIF-1 metabolic signaling
(D) Induces transition from a mesenchymal to pro-neuronal phenotype

**Key:** A

**Solution:** Bevacizumab has not been shown to improve overall survival outcomes in the treatment of newly diagnosed glioblastoma. However, both animal and clinical studies have shown that bevacizumab is effective in the treatment of radiation necrosis. For re-irradiation, the incidence of radiation necrosis is higher than with primary radiation and thus it may be expected that bevacizumab will reduce the incidence of radiation necrosis. Bevacizumab, an angiogenesis inhibitor, does not alter MGMT methylation status or glioblastoma phenotype.

**References:** Schnell et al. J Neurooncol. 2016 Dec; 130(3):591-599.
216. What minimum testicular radiation dose is likely to result in permanent sterility?
   (A) 0.5 Gy in a single dose
   (B) 0.5 Gy in a fractionated regimen over 2 weeks
   (C) 3 Gy in a fractionated regimen over 2 weeks
   (D) 3 Gy in a single dose

Key: C
Solution: Permanent sterility in a male requires a single dose in excess of 6 Gy. Fractionated doses cause more
gonadal damage in males than single doses; 2-3 Gy fractionated over 2 weeks can cause permanent sterility. Doses
of 0.5 Gy and below can result in oligospermia or azoospermia, a temporary sterility. The dose required for
permanent sterility in females varies by age; in a prepubertal female, doses of 12 Gy are required to cause
permanent sterility.
Williams and Wilkins.

217. How does the XIAP protein function in apoptosis?
   (A) Inhibit caspases
   (B) Activate Ligase IV
   (C) Release RAD23A
   (D) Inhibits ERCC1

Key: A
Solution: XIAP (X-linked Inhibitor of Apoptosis Protein) acts to inhibit caspase 3 as well as caspases 7 and 9. BCL-2 is
part of a family of proteins that both inhibit and activate apoptotic pathways. The release of cytochrome c from
mitochondria allows it to bind to APAF 1 (Apoptotic Protease Activating Factor 1) and ATP to form an apotosome
which in turn activates caspase 9. SMAC (Second Mitochondrial Activator of Caspases) acts to inhibit XIAP.

218. Why is it difficult to target specific areas of hypoxia as a strategy to overcome tumor radioresistance?
   (A) Tumor hypoxic is irreversible
   (B) Radiation cannot eradicate hypoxic tumor cells
   (C) Hypoxic tumor cells are as sensitive to radiation as non-hypoxic cells
   (D) Tumors have areas of chronic hypoxia as well as cycling/intermittent hypoxia

Key: D
Solution: In addition to areas of chronic hypoxia, areas of tumor also have cycling/intermittent hypoxia
219. Per the Life San Study of Japanese atomic bomb survivors, what BEST describes the dose response and time dependence for leukemia risk?
   (A) Linear dose response with risk decreasing with time
   (B) Linear dose response with risk increasing with time
   (C) Non-linear dose response with risk increasing with time
   (D) Non-linear dose response with risk decreasing with time

Key: D

NOTE: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores).

Solution: The most recent report from the life span study for leukemias as whole has shown a non-linear dose response. Most of the curvature is from acute myelogenous leukemia. While leukemia risks have declined over time, a radiation-induced risk has persisted even out to the 55 year follow up.


220. For pre-pubescent patients, what is the minimum dose (Gy) to the epiphyseal growth plate which can result in reductions in height?
   (A) 2
   (B) 5
   (C) 10
   (D) 35

Key: C

Solution: Doses greater than 10 Gy are associated with abrogation of height. The dose response relationship may most steep between 15-20 Gy, but continues as a function of higher doses.


221. Which agent is regarded as a radiosensitizer?
   (A) Taxol
   (B) Avastin
   (C) Cisplatin
   (D) Tirapazamine

Key: C

Solution: Concurrent administration of radiation and chemotherapy has emerged as a dominant form of cancer treatment. Nevertheless, our understanding of the specific mechanisms of interaction between radiation and chemotherapy is still evolving. Biological evidence gained in experimental cell lines and tumors suggests that cisplatin lesions cause repair inhibition of radiation-induced DNA damage affecting both homologous recombination and nonhomologous end joining and therefore act as a radiosensitizer.

222. What mechanism of cell death is characterized by a decrease in size, loss of contact with neighbors, chromatin condensation and membrane protein cross-linking?
(A) Necrosis  
(B) Apoptosis  
(C) Senescence  
(D) Autophagy

**Key: B**

**Solution:** Apoptosis is a well-studied programmed cell death process that digests important cellular constituents such as genomic DNA while the cellular membrane fragments and incorporates these components into membrane bound vesicles term “apoptotic bodies”. These bodies can be later phagocytized by surrounding cells avoiding an immune response. Necrosis, on the other hand, is thought to result from the loss of the cells ability to maintain ionic homeostasis. Here the cell membrane swells and eventually ruptures spilling cellular contents into the surround medium. This can engender an immune response. Senescence occurs when cells are permanently blocked from active cell division. While these are reproductively “dead”, they remain metabolically active. Autophagy is a process whereby damaged or unwanted cellular components are “recycled” within double-membraned “autophagosomes”. A form of programmed cell death is associated with the presence of autophagosomes but it is unclear whether these bodies are engaged with


223. Which of the following assays measures local tumor control after RT?
(A) TCD50  
(B) Regrowth  
(C) Wound healing  
(D) Tail vein injection

**Key: A**

**Solution:** Tail vein injection assays are designed to assess the ability of a cell to extravasate from the bloodstream and develop metastatic deposits. Wound healing assays are in vitro assays that investigate the ability of a cell to migrate across a “wound”. TCD50 assays are used to determine the dose of radiation required to achieve local control in 50% of tumors. Tumor growth delay assays assess the ability to a treatment to slow tumor growth.

**References:** Radiobiology for the Radiologist. Hall and Giaccia.  
224. What is the OER for very high LET particles with energy above 300 KeV/µ?
   (A) 0-1
   (B) 2-3
   (C) 4-5
   (D) 6-7

**Key:** A

**Solution:** For LET irradiations, damage occurs via direct action and this is independent of oxygen-mediated killing events/processes therefore the OER approaches unity.


225. Which DNA repair process is generally not considered important in radiosensitivity?
   (A) Base excision repair
   (B) Nucleotide excision repair
   (C) Homologous recombination
   (D) Non-homologous end joining

**Key:** B

Irradiation-induced damage and the DNA damage response. CRC Press; Reference ISBN 9780340929667.

226. Defects in which DNA repair mechanism are associated with Xeroderma Pigmentosum?
   (A) Mismatch Repair (MMR)
   (B) Base Excision Repair (BER)
   (C) Nucleotide Excision Repair (NER)
   (D) Homologous Recombination (HR)

**Key:** C

**Solution:** Mutations in NER results in UV sensitivity syndromes, but no impact on radiation sensitivity.

**References:** Radiobiology for the Radiologist. Hall and Giacca 2012. page 17-18. Lippincott Williams & Wilkins. 7th Ed.
Irradiation-induced damage and the DNA damage response. by CRC Press; Reference ISBN 9780340929667.
227. How does the slope of the survival curve change with more potentially-lethal damage (PLD) repair?

(A) Increases  
(B) Decreases  
(C) No change  
(D) Increases then decreases

**Key:** B  
**Solution:** The slope decreases because cell survival is increased through the action of PLD repair.  

228. What is a commonly observed radiation toxicity following TBI (12 Gy in 6 Fx) for allogeneic transplantation?

(A) Parotidis  
(B) The GI syndrome  
(C) The CNS syndrome  
(D) Tumor lysis syndrome  

**Key:** A  
**Solution:** Acute parotidis occurs in 74% of patients within 24 hours following TBI. Tumor lysis syndrome occurs when chemosensitive leukemias or high grade lymphomas respond rapidly to chemotherapy, leading to electrolyte abnormalities. TLS following TBI is rare. The GI and CNS syndromes are observed following >10 and >50 Gy in single exposures, such as during nuclear accidents.  
**References:** Chaillet MP, Prospective study of the clinical symptoms of therapeutic whole body irradiation, Health Phys. 1993 Apr; 64(4):370-4.

229. Which chromosome aberration is considered the hallmark of radiation exposure?

(A) Micronucleus  
(B) Terminal deletion  
(C) Dicentric exchange  
(D) Reciprocal translocation  

**Key:** D  
**Solution:** Reciprocal translocation can be stable lesions (unlike micronucleus, terminal deletions and Dicentric exchanges that are lethal or lost at division) and are therefore evident in cells many divisions after irradiation; consequently, they are considered a hallmark of radiation exposure.  
Basic radiobiology.  
230. What is more likely to occur with low dose rate compared with high dose rate exposure?
   (A) Repair of sub-lethal lesions
   (B) Interaction of sub-lethal lesions
   (C) Repair of potentially lethal damage
   (D) Interaction of potentially lethal lesions

**Key:** A

**Solution:** Repair of sub-lethal lesions during the protracted low-dose rate exposure


231. Which of the following complexes is involved in sensing DNA double strand breaks?
   (A) Ku70 Ku80
   (B) MRE11/RAD50/NBS1 (MRN)
   (C) Replication protein A (RPA)
   (D) XRCC4 and XLF/Cernunnos

**Key:** B

**Solution:** In addition to the rapid recruitment of Ku to DSBs, additional proteins or histone modifications assemble in a choreographed process at DSBs. The phosphatidylinositol 3- kinase-related kinase, ataxia telangiectasia mutated (ATM) lies at the core of DDR signalling. NHEJ predominantly occurs independently of DDR signalling and vice versa. The MRE11/RAD50/NBS1 (MRN) complex represents the major DSB sensor, which recruits ATM via an interaction with the C-terminus of NBS1, promoting ATM autophosphorylation and conversion of an inactive dimer to an active monomer. ATM rapidly phosphorylates H2AX, a variant of H2A, promoting chromatin binding of mediator of damage-checkpoint 1 (MDC1). MDC1 interacts with MRE11, tethering MRN and, hence, ATM, at the DSB. Thus, ATM consecutively extends the region of phosphorylated H2AX (gH2AX), amplifying the DDR signal.


232. In which organ does amifostine (WR-2721) NOT function as an effective radioprotector?
   (A) Brain
   (B) Esophagus
   (C) Salivary gland
   (D) Bone marrow

**Key:** A

**Solution:** Amifostine is an accepted radioprotector but animal studies have demonstrated it does not cross the blood brain barrier.

**References:** Variation in normal tissue responsiveness to WR-2721, (1984).
233. Which method can be used to directly measure tumor oxygenation?

(A) Interstitial oximetry
(B) Photoacoustic imaging
(C) Pimonidazole immunohistochemistry
(D) Carbonic anhydrase IX (CA-IX) immunohistochemistry

Key: A

Solution: Photoacoustic imaging is an ultrasound-based approach to measure hemoglobin oxygen saturation. While both CA-IX and pimonidazole are used as markers of hypoxia within tissues, only interstitial oximetry is used to measure oxygen levels within a tissue.

Lee and Dewhirst Antioxid Redox Signal. 2014 Jul 10; 21(2): 313-337.

234. Regarding very High LET radiations:

(A) effects are enhanced by radiosensitizers.
(B) it directly improves oxygen flow to the tumor.
(C) damage results mainly from oxygen free radicals.
(D) it induces direct DNA damage independent of oxygen radicals.

Key: D

Solution: High LET radiation induces direct DNA damage rather than through oxygen free radicals


235. For patients with glioblastoma, the addition of temozolomide to radiation is associated with improved OS and increased:

(A) chemotherapy induced diarrhea.
(B) methylation of the promoter region of MGMT gene.
(C) incidence of pseudoprogression following chemoRT.
(D) degradation of the protein product of the MDR1 (multi-drug resistance) gene.

Key: C

Solution: In the Stupp study, the addition of concurrent and adjuvant temozolomide improved overall survival. In cultured glioblastoma cells, temozolomide treatment induces expression of the MGMT gene product. Methylation of the MGMT promoter region would be associated with lower MGMT expression. Increased expression of the MDR gene product would be expected to induce chemotherapy resistance following exposure. While temozolomide is not associated with diarrhea, the incidence of pseudoprogression following combined chemoradiation is increased.

236. What main gestational effects would be expected following 1 Gy irradiation during periods of 8-15 weeks?

(A) No change in IQ score
(B) Microcephaly and shorter stature
(C) Higher rates of mental retardation
(D) Significant congenital malformations

**Key:** C  
**Solution:** The effects of radiation to the embryo and fetus depend upon the stage of gestation, the dose, and the dose rate. Congenital malformations are seen with radiation in the early (2-6 weeks) phases of development. Severe mental retardation is nearly 4 times more common if the radiation is received between 8 and 15 weeks than if it is received later. Children exposed in utero are shorter, lighter, and have a smaller head diameter than those not exposed to radiation.  

237. Which of the following chromosomal aberrations is NOT lethal?

(A) Ring  
(B) Dicentric  
(C) Anaphase bridge  
(D) Symmetric translocation

**Key:** D  
**Solution:** Rings, Dicentrics and Anaphase Bridges are classically defined as lethal lesions as they lead to aberrant mitosis’ while symmetric translocations can be stable events and not produce cell death at mitosis as no DNA is lost.  
**References:** Hall, E.J. Radiobiology for the Radiologist, (2012) -page 26-29, 7th Ed.

238. Which caspase is common to both the cellular apoptosis that occurs by death-receptor mediated (external) and mitochondrial mediated (Internal) pathways?

(A) Caspase 3  
(B) Caspase 7  
(C) Caspase 9  
(D) Caspase 11

**Key:** A  
**Solution:** Death-receptor mediated pathway involves caspase 8 and mitochondrial-mediated pathway involves caspase 9, both pathways converge to caspase 3.  
239. How is the ATM protein activated in response to radiation-induced DNA double strand breaks?
(A) Interaction and cleavage by DNA-PKcs
(B) Via protein ubiquitination from activated Rad50
(C) Interaction with Ku70 and Ku80 at sites of DNA DSB
(D) Auto-phosphorylation converting inactive dimer to an active monomer

Key: D

Solution: A functional MRN complex is required for ATM activation after double strand breaks (DSBs). The complex functions upstream of ATM in mammalian cells and induces conformational changes that facilitate an increase in the affinity of ATM towards its substrates, such as CHK2 and p53. Inactive ATM is present in the cells without DSBs as dimers or multimers. Upon DNA damage, ATM autophosphorylates on residue Ser1981. This phosphorylation provokes dissociation of ATM dimers, which is followed by the release of active ATM monomers.


240. Elevated EGFR expression levels in the primary head and neck squamous cell carcinoma have been correlated with decreased survival. How are EGFR expression levels elevated?
(A) Gene amplification
(B) Transcriptional deregulation
(C) EGFR receptor dimerization
(D) transactivation by G-protein-coupled receptors (GPCR)

Key: A

Solution: EGFR status was analyzed in 86 tumor samples from 82 HNSCC patients by fluorescent in situ hybridization (FISH). High EGFR gene copy number by FISH is frequent in HNSCC and is a poor prognostic indicator.

241. The formation of which chromatid aberration is generally considered a lethal event?

(A) Ring
(B) Dicentric
(C) Anaphase bridge
(D) Terminal deletion

Key: C
Solution: Ring (DSB in each arm of a chromatid in G1) and Dicentric (two DSBs interacting on two separate chromosomes) are chromosome aberrations, while an anaphase bridge is two DSBs with one DSB in both chromatids of the same chromosome. Terminal lesions are not generally considered lethal events.


242. About 2/3 of biological damage after low LET irradiation is caused by:

(A) S· - free radical.
(B) e- - free electron.
(C) H2O+ - the ion free radical.
(D) OH· - the hydroxyl free radical.

Key: D
Solution: OH· - the hydroxyl free radical are produced by secondary reactions in radiolysis of water. OH•, the hydroxyl free radical, diffuses in tissue within a cylinder about 4nm in diameter (about 2x diameter of a DNA double helix) and causes about 2/3 of all biological damage: half-life – 10-9 seconds.


243. What is the purpose of ovarian transposition prior to RT in premenopausal women?

(A) Induce early menopause
(B) Improved tumor response
(C) Protect the reproductive function
(D) Preserve the endocrine function

Key: D
Solution: The purpose of ovarian transposition in a 30-year old patient is to preserve the endocrine function of the ovaries, preventing early menopause. Despite transposition, there is enough scatter radiation dose to severely impact reproductive function. To maintain reproductive function, harvesting of oocytes would be required and this requires 10-14 days for stimulation and would need to be performed before radiation.

244. Historically, what are the reported toxicities for patients with ataxia telangiectasia following RT?
   (A) Increased acute toxicity only
   (B) Decreased late toxicity only
   (C) Increased acute and increased late toxicity
   (D) No difference in acute and late toxicities

**Key:** C  
**Solution:** AT patients experienced severely increased acute AND late toxicities following radiation, indicating that the efficiency of DNA repair is important across both categories of toxicity.  

245. To obtain the BEST tumor radiosensitization when should hyperthermia be combined with radiation?
   (A) One hour before RT  
   (B) One hour after RT  
   (C) Two hours after RT  
   (D) Simultaneously with RT

**Key:** D  
**Solution:** Hyperthermia is most effective radiosensitizer if given at the time of radiation. However, the best therapeutic effective is achieved using sequential heat treatment rather than simultaneous treatment. Sequential treatment spares normal tissue injury because of differences in blood flow between tumor and normal tissues.  
**References:** Moyer HR, Delman KA., The role of hyperthermia in optimizing tumor response to regional therapy,(2008).  

246. What is an advantage of alpha emitter Ra-223 versus beta emitters for the treatment of bone metastasis?
   (A) Higher LET/RBE  
   (B) Shorter half-life  
   (C) Easier to administer  
   (D) Greater tissue penetration

**Key:** A  
**Solution:** Alpha emitters are high LET.  
247. Which methodology is used to measure the reproductive integrity of cells after radiation exposure?

(A) MTT proliferation assay
(B) Ki-67 Labeling index
(C) Clonogenic survival assay
(D) Potential doubling time (T pot) assay

**Key:** C

**Solution:** Radiosensitivity is defined by the ability of an irradiated single cell to form a surviving viable colony of more than 50 cells (>6/7 cell divisions). The Puck and Marcus clonogenic survival assay measures the ability of single cells to form multicellular colonies. MTT measures short-term proliferation and not clonogenicity. Ki-67 and Tpot assess proliferative indexes.


248. Which agent is used to ameliorate radiation induced mucositis during TBI?

(A) Palifermin
(B) Amifostine
(C) Pentoxifylline
(D) Sulfasalazine

**Key:** A

**Solution:** Palifermin is a recombinant keratinocyte growth factor shown in a randomized phase III trial to reduce oral mucositis in patients who receive total body irradiation. There is some evidence for the use of amifostine to lessen xerostomia in patients receiving radiation for head and neck cancer, but no evidence for reduction of mucositis. Pentoxifylline is used as a treatment for late radiation toxicities, such as non-healing ulcers. Sulfasalazine was once recommended for the prevention of radiation colitis, but a phase 3 trial demonstrates no benefit.

**References:** Stiff PJ, Palifermin reduces patient-reported mouth and throat soreness and improves patient functioning in the hematopoietic stem-cell transplantation setting, (2006) 24(33) page 5186-93.

249. What does the beta parameter generally describe in the Linear Quadratic survival model?

(A) Initial slope
(B) Repair capability
(C) Complex lesions
(D) Irreparable lesions

**Key:** B

**Solution:** One simple idea is that the linear component \(\exp(-\alpha D)\) might result from single-track events that are generally considered lethal, while the quadratic component \(\exp(-\beta D^2)\) might arise from two-track events that are generally considered sub-lethal, and therefore \(\beta\) can be considered to represent repair capability (or the ability to accumulate and repair sublethal events).

250. For a given isoeffect survival level, how does the OER change as the LET increases from 10 - 100 keV/micron?
(A) Decreases  
(B) Increases  
(C) Remains the same  
(D) Decreases then increases

Key: A
Solution: As the LET increases, the contribution of direct action to cell killing of radiation increases, ergo the contribution of oxygen-mediated indirect effects to cell killing decreases, and hence the OER reduces.

251. What is the typical doubling time for human tumor cells?
(A) 6 hrs  
(B) 48 hrs  
(C) 96 hrs  
(D) 2 weeks

Key: B
Solution: Human tumor cells can divide in 24-36 hours given ideal growth conditions and nutrients, but heterogeneity in cell population dynamic and growth in tissue culture generally mean that not all cells have an ideal growth environment, and therefore typical doubling times for a population of cells have been found to be around 48 hours.

252. Which can facilitate normal tissue recovery after radiation damage?
(A) ATM inhibition that allow damaged cells to die  
(B) CDK 4/6 inhibition to arrest cell division at G1 checkpoint  
(C) HIF-1a inhibition that prevents increase in angiogenesis  
(D) DNA PK inhibition that prolongs the presence of γH2AX

Key: B
Solution: Cyclin-dependent kinase (4/6) inhibition that stops cell division and arrest at G1 enables more DNA repair
253. What assumptions does the relative risk model for radiation induced carcinogenesis make?
(A) It increases the natural incidence of cancer at all ages
(B) It increases cancer incidence in people 30 years following exposure
(C) It increases cancer incidence over that occurring naturally irrespective of the natural level
(D) It increases cancer incidence relative to background frequencies found in people older than 65

Key: A
Solution: The relative risk model produces an increase in cancer risk at all ages. As the probability of expression of spontaneous cancers increases with age, so will the number of radiation-induced cancers. The absolute risk model assumes that radiation “adds” a level of incidence above that which occurs in a natural population. This risk is constant and does not vary with age. The time-dependent relative risk model assumes that risk can vary with age at exposure and time since exposure.

254. Which of the following chromosomal aberrations is formed from a radiation-induced break in each arm of a single chromatid in G1?
(A) Ring
(B) Dicentric
(C) Anaphase bridge
(D) Asymmetric translocation

Key: A
Solution: Ring (chromosome aberration) DSB in each arm of a chromatid in G1 (early in interphase prior to replication) with two DSBs rejoin to form a ring and a fragment. Dicentric (chromosome aberration) is interaction of one DNA double strand break on two separate chromosomes producing one chromosome with two centromeres + an acentric fragment. Anaphase bridge (chromatid aberration) and a post replication chromosome event, One DSBs in both chromatids of same chromosome (two DSBs) to produce a ring-like structure plus fragment. An asymmetric translocation involves to DSBs in separate chromatids or chromosomes.

255. Which of the following is approved for use as a radiation protector in the event of a radiation emergency?
(A) Cisplatin
(B) MESNA
(C) Potassium iodide
(D) Keratinocyte growth factor

Key: C
Solution: Keratinocyte growth factor has been studied for the prevention of radiation mucositis; MESNA is used in reduce the incidence of hemorrhagic cystitis following ifosfamide or cyclophosphamide treatment; cisplatin is a chemotherapy agent that is a radiation sensitizer; none of these compound is approved for use in a radiation emergency. Potassium iodide was approved by the FDA for use in the prevention of thyroid complications following an exposure to radioactive iodine.
256. What is the response and location of stem cells in the intestinal epithelium after fractionated radiation?

(A) Relatively radiosensitive and located within the villi
(B) Relatively radioresistant and located within the villi
(C) Relatively radiosensitive and located at the base of the crypt
(D) Relatively radioresistant and located at the base of the crypt

Key: D
Solution: The intestinal stem cells, now known to be identifiable by the LGR5 marker are relatively radioresistant due to increased reliance on homologous recombination and subsequently regenerate the crypts and villi following radiation. They are located in the crypt.
References: Hua G et al. Crypt base columnar stem cells in small intestines of mice are radioresistant, (2012) page 1266-76; 143(5).
Metcalfe C et al., Lgr5+ stem cells are indispensable for radiation-induced intestinal regeneration, (2014) page 149-59; 14(2).

257. Per QUANTEC, what are the appropriate dose constraints for single fraction SRS to the optic chiasm?

(A) Mean dose of 7Gy
(B) Maximum point dose of 12Gy
(C) Mean dose of 15Gy
(D) Maximum point dose of 18Gy

Key: B
Solution: The correct answer is B. Damage to any portion of the optic chiasm, even small volumes, may be associated with vision impairment. Hence, maximum point doses, rather than mean doses which would not directly reflect higher dose regions, are the most appropriate to evaluate. A maximum point dose of <12Gy is recommended by QUANTEC.

258. Which type of DNA repair inhibitors will likely have the greatest radiosensitization?

(A) Base excision repair inhibitors
(B) Nucleotide excision repair inhibitors
(C) DNA double-strand break repair inhibitors
(D) Poly ADP ribose polymerase (PARP) inhibitors

Key: C
Solution: Radiation’s primary mechanism of action is through DNA double-strand break, thus DNA double-strand break inhibitor will likely be the most potent
259. Why are PTV margin individualized for each field during proton therapy?
   (A) Uncertainties of dose calibration
   (B) Uncertainties in the location of the Bragg peak
   (C) Uncertainties of CT number to density conversion
   (D) Uncertainties in the location of the microscopic disease

**Key:** B  
**Solution:** Distal and proximal margins along the beam axis depend on proton-specific uncertainties. Various factors impact the actual location of the Bragg Peak in the patient, which has a large impact on the dose distribution along the beam trajectory.  
**References:** Halperin, Perez & Brady's Principles and Practice of Radiation Oncology, (2013), 6th Ed.

260. What are the minimum recommended frequency and tolerance to verify mechanical and imaging isocenter coincidence of volumetric imaging systems (e.g.: CBCT) on modern linacs?
   (A) Daily & ≤ 0.5 mm
   (B) Daily & ≤ 2.0 mm
   (C) Monthly & ≤ 0.5 mm
   (D) Monthly & ≤ 2.0 mm

**Key:** B  
**Solution:** Based on the TG-142 recommended guidelines, mechanical and imaging isocenters should be verified on a daily basis and agreement should be within 2mm (non-SRS machine).  

261. Which of the following BEST describes the methodology to generate an internal target volume (ITV)?
   (A) GTV + Setup Margin
   (B) CTV + Setup Margin
   (C) GTV + Internal Margin
   (D) CTV + Internal Margin

**Key:** D  
**Solution:** Based on ICRU 62, the ITV is defined as the CTV + the internal margin (IM).  
**References:** ICRU report No.62, (1999) -International commission on radiation units and measurements.

262. What are typical prescription isodose lines for intracranial SRS for linac and Gamma Knife, respectively?
   (A) 50; 80
   (B) 50, 100
   (C) 80; 50
   (D) 100, 50

**Key:** C  
**Solution:** Linac based SRS is typically prescribed to the 75-85% isodose line whereas Gamma Knife treatment is usually prescribed to the 50% isodose line.  
263. Which of the following can NOT be used to accelerate protons clinically?

(A) Cyclotron
(B) Magnetron
(C) Synchrotron
(D) Linear accelerator

**Key:** B  
**Solution:** Current clinical proton therapy beams are generated using synchrotrons or cyclotrons. Linear accelerators can be used to accelerate protons to clinical energies but consideration must be given to the length of the accelerating cavity. A magnetron is used to generate RF power in a linear accelerator and not to accelerate protons.  
**References:** Khan, F.M. The Physics of Radiation Therapy, 6th Ed.

264. Why does a kV cone beam CT (CBCT) provide more robust image localization than an orthogonal kV pair?

(A) Speed  
(B) Greater spatial resolution  
(C) 3-dimensional information  
(D) Less susceptibility to patient movement

**Key:** C  
**Solution:** kV-CBCT provides three dimensional information for patient localization that planar projection imaging cannot.  

265. The signal in a calibrated ion chamber used to measure photon beam dose is directly proportional to what quantity?

(A) Exposure in ion chamber  
(B) Ionization of air in chamber cavity  
(C) Photon interactions in the surrounding water  
(D) Charge particles created in the wall of the chamber

**Key:** B  
**Solution:** The photons interact with the water and wall of the chamber to produce charged particles (electrons) that cross the cavity. These electrons ionize the air in the cavity and are attracted to the charged central electrode. It is this current that is measured. Modern calibration protocols (AAPM TG51 and IAEA TRS-398) are based on absorbed dose to water. Earlier protocols were based on exposure in air.  
**References:** AAPM TG 51,1999; Kahn, Physics of Radiation Therapy. 6th ed., Chapter 4: Measurement of Absorbed dose.
266. What is the energy of a 23 MV photon that scatters at 90° from its original path?
(A) 0.256 MV
(B) 0.511 MV
(C) 11.5 MV
(D) 23 MV

Key: B
Solution: For high energy (MV) photons, if the scatter angle of the scattered photon is perpendicular to the incident primary photon direction, the scattered photon energy is approximately equal to the rest mass of an electron independent of the incident primary photon energy. This is important when considering shielding design for high energy linacs.
References: Khan, F.M. The Physics of Radiation Therapy, 6th Ed.

267. Why are high atomic number nuclei unstable?
(A) Short range of the Coulomb force
(B) High binding energy per nucleon
(C) Short range of the strong nuclear force
(D) Excess number of electrons compared to protons

Key: C
Solution: The strong nuclear force provides the “glue” that holds nuclei together against the mutual Coulomb repulsion of the protons. The nuclear force has a short range whereas the Coulomb force does not. For this reason, in large nuclei, the Coulomb repulsion begins to dominate and thereby makes higher atomic number nuclei unstable.

268. Which of the following corrections is needed for the electrometer charge reading during a TG-51 absolute dose calibration?
(A) Magnetic effect
(B) Material density
(C) Temperature and pressure
(D) Chamber volume effect

Key: C
Solution: During a TG-51 calibration, the electrometer reading is corrected to account for all of the following: ion recombination effect, polarity effect, temperature/pressure factor and electrometer correction factor.
References: Khan, FM. The Physics of Radiation Therapy, 6th Ed.
269. Which of the following particles is accelerated in a high-energy linear accelerator for photon production?
(A) Proton
(B) Photon
(C) Electron
(D) Deuteron

Key: C
Solution: The initial source of a high energy linear accelerator in radiotherapy is an electron which is emitted by the electron gun.
References: Khan, FM. The Physics of Radiation Therapy, 6th Ed.

270. Which produces photons of discrete energies?
(A) 6 MV linac
(B) Orthovoltage unit
(C) Van De Graff generator
(D) Cesium-137 source

Key: D
Solution: Unlike bremsstrahlung, Cesium-137 decays and emits a gamma ray with a distinct energy. Other x-rays are produced by bremsstrahlung.
References: Khan, FM. The Physics of Radiation Therapy, 6th Ed.

271. When compared to a multiple isocenter (cone-based) SRS plan, the use of microMLC with a dynamic conformal arc delivery technique will:
(A) decrease delivery time.
(B) worsen target dose fall-off.
(C) reduce target dose coverage.
(D) increase target volume dose heterogeneity.

Key: A
Solution: The use of mMLC for irregularly-shaped lesions will reduce treatment time because of the decrease in the number of isocenters, reduce dose heterogeneity due to the lack of overlapping “shots,” and improve dose fall off.
272. What is a key limitation of optical surface imaging used to guide radiation therapy delivery?
   (A) Imaging dose
   (B) System accuracy
   (C) Real-time monitoring
   (D) Internal target localization

Key: D
Solution: 3D surface imaging has been shown to have high accuracy, accurate real-time motion monitoring and does not add radiation dose. However, because surface imaging localizes based on surface anatomy, discrepancies may exist between the surface and internal target position.

273. What is the primary function of a degrader during TSET treatment?
   (A) Scatter the electron beam
   (B) Remove photon beam contamination
   (C) Increase depth of electron beam penetration
   (D) Decrease depth of electron beam penetration

Key: D
Solution: The primary role of the degrader is to “degrade” the electron beam energy such that the electron beam penetration is reduced. Although the degrader will scatter some of the electron beam, the primary role is to degrade the energy.

274. The absorption edge phenomenon is associated with which photon-electron interaction?
   (A) Compton effect
   (B) Pair-production
   (C) Coherent scattering
   (D) Photoelectric effect

Key: D
Solution: As the energy of a photon increases above the electron binding energy in a particular atomic shell, a new channel of absorption for the photon suddenly becomes available during the photoelectric effect. This leads to an abrupt increase (edge) in the attenuation coefficient as the energy increases.
275. Why is the maximum dose for a superficial energy x-ray beam at the skin surface?

(A) Small half value layer thickness
(B) Short range of secondary electrons
(C) Predominance of photoelectric effect
(D) Significant electron beam contamination

**Key:** B

**Solution:** The location of $d_{\text{max}}$ is determined by the range of secondary electrons set in motion by the photons. For superficial energy x-rays, this range is small and therefore such beams do not exhibit a build-up region/skin sparing effect.


276. Biologically-based, inverse optimization for IMRT treatment planning is best described as an optimization method that:

(A) uses criteria such as TCP, NTCP, and EUD.
(B) uses pre-populated QUANTEC dose constraints.
(C) accounts for fractionation in the optimization.
(D) accounts for patient specific dose responses.

**Key:** A

**Solution:** Biologically-based inverse optimization is a specific method that uses biological criteria such as TCP and NTCP to determine the ideal treatment plan.


277. The most stable heavy atomic nuclei have ______ protons than neutrons and an ______ number of protons

(A) More, even
(B) Fewer, even
(C) More, odd
(D) Fewer, odd

**Key:** B

**Solution:** Stable heavy nuclei have fewer protons than neutrons and an even number of protons. The most stable nuclei also have an even number of neutrons.

278. Which of the following BEST describes the behavior of the photon beam PDD?

(A) Decreases with increasing field size
(B) Is independent of electron contamination
(C) Increases with increased source to surface distance
(D) Decreases with increasing photon beam energy beyond dmax

**Key:** C

**Solution:** The presence of electron contamination will change the location of Dmax and therefore the amount of electron contamination will affect the PDD for a given nominal photon energy. A and D both increase instead of decrease.

**References:** Khan, FM. The Physics of Radiation Therapy, (2003) -page 162, 164, 166, 211. 3rd Ed.

279. For an image of a bone reading 400 HU, what is the percent change, with respect to water, of its linear attenuation coefficient?

(A) 0.4%
(B) 4.0%
(C) 40%
(D) 400%

**Key:** C

**Solution:** Hounsfield units (HU) relate the linear attenuation coefficient (µ) of water to that of other material. HU are defined \( \frac{(µ_{\text{tissue}} - µ_{\text{water}})}{µ_{\text{water}}} \times 1000 \). Therefore, a change of 1 HU corresponds to a 0.1% change from the attenuation coefficient of water.

**References:** Khan, FM. The Physics of Radiation Therapy, 6th Ed.

280. What is the accepted RBE value for proton therapy?

(A) 0.96
(B) 1.1
(C) 1.6
(D) 2.0

**Key:** B

**Solution:** The widely accepted RBE for protons (relative to 250 kVp photons) is 1.1. Currently, there is no agreement on refining this value based on specific tissue, energy or dose values.

281. With what device is a wedge profile generated using an enhanced dynamic wedge (EDW) technique?
   (A) MLC
   (B) Bolus
   (C) Physical wedge
   (D) Secondary jaws

   **Key:** D
   **Solution:** An enhanced dynamic wedge is different than a physical wedge; with a physical wedge, a physical piece of material is placed in the beam path. A wedged dose distribution from an enhanced dynamic wedge is instead created by dynamically moving the jaws across a beam while the beam is on. MLCs nor bolus are involved.

282. Why is the radiation dose enhanced proximal to a metal prosthesis?
   (A) Backscatter from the metal
   (B) Attenuation from the metal
   (C) Pair production within the metal
   (D) Temperature elevation within the metal

   **Key:** A
   **Solution:** Metal increases electron backscatter due to its high atomic number. Photon attenuation is increased within the metal, but does not cause the enhanced proximal dose. Pair production impacts dose distal to the metal, as opposed to proximal. The temperature of the metal does not apply.

283. Which method results in the sharpest penumbra for a half beam blocked field?
   (A) MLC
   (B) Primary collimator
   (C) Secondary collimator
   (D) Cerrobend™ lead alloy blocks

   **Key:** D
   **Solution:** Larger SDD (source to device distance) yields better (smaller) geometric penumbra. The cerrobend™ results in the sharpest penumbra, then the MLC, then the secondary collimator (jaw.) The primary collimator is the static collimator located in closest to the target in the linac head. Disadvantage of Cerrobend™ blocks is increased scatter & e-dose (higher skin dose) and they are heavy and individually made.
   **References:** Khan, FM. The Physics of Radiation Therapy, 6th Ed.
284. What is the MOST appropriate response to an HDR source that is “stuck” in an applicator inside a patient?  
(A) Restart the treatment console and initialize check cable  
(B) Cut the transfer cable and place the source in a shielded container  
(C) Remove the applicator from the patient and place it in a shielded container  
(D) Disconnect the transfer tube from the indexer and then rotate the indexer  

**Key:** C  
**Solution:** If the source cannot be retracted either automatically or manually, the applicator should be withdrawn from the patient and placed in a shielded container. Cutting the cable is not recommended.  

285. What is a greater concern with spot scanning technique versus passive scattering for proton therapy delivery?  
(A) Energy selection  
(B) Beam shaping  
(C) Target motion  
(D) Beam line length  

**Key:** C  
**Solution:** Spot scanning involves sequential “painting” of the target with a narrow beam producing dose spots. Target motion is more difficult to deal with under these circumstances.  

286. All of the following radiation therapy information is exported in DICOM-RT format EXCEPT:  
(A) CT Images.  
(B) Volume Dose.  
(C) Structure Set  
(D) Treatment Plan.  

**Key:** A  
**Solution:** The dose, plan, and structures are exported in DICOM-RT format while the CT is exported in DICOM. The DICOM-RT format was specifically designed for items solely associated with radiation therapy.  
**References:** Law, Maria YY & Liu, Brent, -Radiographics 29(3); (2009) p655-670.
287. Which of the following interactions is most likely for a 2 MV photon in cortical bone?
   (A) Pair production
   (B) Compton scatter
   (C) Photoelectric effect
   (D) Photonuclear interaction

Key: B
Solution: Compton interaction are the most common in the range of energies used for Radiation Therapy for low Z biological materials in the human body.

288. A solution using multiple criteria optimization (MCO) is one in which:
   (A) the minimum value of the objective function is found.
   (B) the criteria with the highest weighing factor has been met.
   (C) improving an objective is impossible without deteriorating another.
   (D) all target dose objectives are met and RAR objectives are minimized.

Key: C
Solution: Modern planning systems are starting to use multiple criteria optimization to assess the trade-off between a set of mutually contradictory objectives. There may be several solutions for which improving an objective is impossible without deteriorating another. These are called Pareto solutions and the set of these solutions are called the Pareto front.

289. What causes the star shaped streak artifacts seen in a CT image taken for post-prostate seed implant dosimetry?
   (A) Prostate edema
   (B) Prostate motion
   (C) Emitted radiation from implanted seeds
   (D) Metal from the implanted radioactive seeds

Key: D
Solution: In a prostate seed implant brachytherapy procedure, radioactive seeds encased in metal are implanted into the prostate. The metal from these seeds causes metal artifacts, namely in the form of star-shaped streaks. Metal artifacts are caused by incomplete attenuation profiles, beam hardening, and scatter effects.
290. Which imaging technique delivers the lowest dose?
   (A) Orthogonal kV image pair
   (B) Single CT scan for patient simulation
   (C) Single kV-CBCT for patient positioning
   (D) Orthogonal MV-EPID image pair for patient positioning

   **Key:** A
   **Solution:** C will be less than 1 cGy, others will be in the range of 1-6 cGy.

291. By definition, the TMR and PDD are both equal to 1.00 at depth of dmax. For depths greater than dmax, TMR is larger than PDD because:
   (A) of the Mayneord effect.
   (B) of the divergence of the field.
   (C) TMR accounts for scatter in phantom.
   (D) TMR does not include inverse square attenuation.

   **Key:** D
   **Solution:** The TMR does not include the effects of inverse square attenuation and therefore it does not decline as rapidly as the PDD. Both PDD and TMR account for phantom scatter.
292. Which of the following curve parameters on this normalized, differential PTV DVH would be best to describe the dose homogeneity within the target?

(A) Height
(B) Width
(C) Center value
(D) Largest value

**Key:** B

**Solution:** A normalized, differential DVH can be used to assess the percentage of volumes of the PTV that receive specific doses. The height of the curve will correspond to the most likely dose while the width of the curve can be used to measure the spread of doses—i.e. the uniformity of dose within the PTV. The largest value of the curve will denote the maximum dose.

**References:** Khan, FM. Treatment Planning in Radiation Oncology, 2nd Ed. Ch16-258.

293. Prior to the first treatment fraction, what does a patient-specific IMRT QA measurement verify?

(A) Treatment plan matches dose objectives
(B) Treatment delivery matches planned dose
(C) Coincidence of imaging and treatment isocenter
(D) Absolute output of the linac under plan parameters

**Key:** B

**Solution:** Patient specific IMRT QA involves delivering the patient’s plan onto a radiation detector, then comparing the delivered dose distribution to that of the plan. The purpose is to ensure that the patient’s plan can be accurately and safely delivered.

**References:** Khan, FM. The Physics of Radiation Therapy, 6th Ed.
294. The mass of the nucleus relative to the sum of the masses of the protons and neutrons is:
   (A) slightly larger.
   (B) slightly smaller.
   (C) significantly smaller.
   (D) significantly larger.

Key: B
Solution: The mass of the nucleus is slightly smaller than the sum of the masses of the protons and neutrons due to their nuclear bonding energy (i.e. mass defect).
References: Khan, FM. The Physics of Radiation Therapy, 6th Ed.

295. What is the advantage of the DICOM image format?

   (A) Reduction of imaging dose
   (B) Increased image resolution
   (C) Improved image sharing reliability
   (D) Patient information is not stored with image files

Key: C
Solution: DICOM is the standard format for storing images. It is not related to the inherent resolution or resulting dose of acquiring images. Patient information is stored with imaging files. Due to the standardized format and inclusion of patient information, DICOM improves the reliability of storing and sharing images.

296. To release a patient with a permanent brachytherapy implant from the hospital, what is the maximum allowable dose equivalent to any other individual?

   (A) 0.5 mSv
   (B) 1.0 mSv
   (C) 5.0 mSv
   (D) 1.0 mSv

Key: C
Solution: The external dose rate from the patient must be measured prior to release from the hospital to ensure that the “total effective dose equivalent to any other individual from exposure to the released individual is not likely to exceed 5 millisieverts (0.5 rem).”
297. A pregnant patient receives radiation to the brain using parallel-opposed beams. What source of radiation will most likely contribute to the fetus?

(A) Primary radiation  
(B) Leakage radiation  
(C) Patient scatter radiation  
(D) Collimator scatter radiation

Key: B  
Solution: At distance > 30cm, the primary source of radiation is leakage radiation.  

298. What type of training is needed in order to receive shipped packages containing radioactive materials?

(A) Hospital specific radiation safety training  
(B) Certification by the American Board of Radiology  
(C) Training on Department of Transportation regulations  
(D) High dose rate brachytherapy annual emergency training

Key: C  
Solution: Only qualified trained individuals can ship and receive radioactive packages. Since hazardous materials shipping is regulated by the DOT, option C is correct.  

299. In general, respiratory motion management techniques should be considered if the range of target motion in any direction is greater than:

(A) 2 mm.  
(B) 5 mm.  
(C) 10 mm.  
(D) 20 mm.

Key: B  
Solution: A 5 mm motion limit criterion value is chosen because this level of motion can cause significant artifacts and systematic errors during imaging procedures.  

300. In low atomic number media (water or tissue), a 12 MeV electron beam loses energy predominately through which of the following processes?

(A) Inelastic collisions with nuclei  
(B) Elastic collisions with nuclei  
(C) Elastic collisions with atomic electrons  
(D) Inelastic collisions with atomic electrons

Key: D  
Solution: In low Z medium, electrons lose energy predominately through ionizing events with atomic electrons. If the medium has a higher Z, there is an increase in the inelastic collisions with nuclei—i.e. bremsstrahlung production.  
References: Khan, FM. The Physics of Radiation Therapy, 6th Ed.