Rhabdomyosarcoma (RMS)

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Epidemiology

• RMS is the most common pediatric soft tissue sarcoma
  – 40% of all pediatric soft tissue sarcomas
  – 350 cases/year in the USA

• Slight male predominance

• Peak age is between 2 – 5 years of age
Pathology: What is the differential?
Pathology

• This is a **small round blue cell tumor**
  
  – **MR LEMONS** (mnemonic): Melanoma, **rhabdomyosarcoma**, lymphoma, Ewing's sarcoma, medulloblastoma, olfactory (esthesioneuroblastomas), neuroblastoma, small cell carcinoma

• Generally, RMS is divided into 3 histologic subtypes (arranged from the most favorable to the least favorable prognosis)
  
  – **Embryonal** (**75% of RMS cases**)  
    • Includes botryoid and spindle variants
  
  – **Alveolar** (**25% of RMS cases**)
  
  – **Pleomorphic / Undifferentiated**
Genetics

- **Embryonal**
  - Loss of heterozygosity of 11p15.5

- **Alveolar**
  - Translocations of:
    - **t(2:13)**
      - Chromosome 2: PAX3
      - Chromosome 13: FOX01 (Forkhead box protein O1, also called FKHR or FORKHEAD)
    - **t(1:13)**
      - Chromosome 1: PAX7
      - Chromosome 13: FOX01 (Forkhead box protein O1, also called FKHR or FORKHEAD)
  - These translocations result in **PAX-FOXO1 Fusion Genes** = Forkhead fusion patients have a worse prognosis
Anatomic Sites

• RMS can occur almost anywhere in the body

• The head and neck region is the most common site of RMS
  – This includes para-meningeal head and neck, non para-meningeal head and neck, orbit

• The GU tract is second most common
Clinical Presentation and Workup

• RMS usually presents as an **asymptomatic mass**, but this is site dependent

• Universal:
  – H&P with CBC, CMP, LFTs, UA
  – CT/MRI of the primary site
  – PET CT (or CT CAP and bone scan)
  – Biopsy the primary site
  – Bone marrow biopsy

• Site Dependent
  – Lumbar puncture if parameningeal tumor (if CSF positive, obtain MR spine)
  – Sentinel lymph node biopsy for extremity cases
  – Ipsilateral retroperitoneal lymph node dissection for paratesticular sites in boys age greater than 10
Risk Stratification

• In RMS, there is **pre-operative staging** and **post-operative grouping**
  – Combining these will lead to a **risk group (low, intermediate, high)** which will determine treatment

• **Staging**
  – TNM not often used
  – Depends on site, size, and nodal involvement
    • There are favorable sites and unfavorable sites

• **Grouping**
  – Depends on possible extent of surgical resection; *the group is assigned at the time of initial diagnosis*
## Staging

### TABLE 56.5: IRSG Staging System

<table>
<thead>
<tr>
<th>Stage</th>
<th>Sites</th>
<th>Size</th>
<th>N</th>
<th>M</th>
<th>3-yr Failure-Free Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: Favorable site</td>
<td>Orbit, Head and Neck (non-PM), GU (non-bladder/prostate), Biliary tract</td>
<td>Any size</td>
<td>Any N</td>
<td>M0</td>
<td>86%</td>
</tr>
<tr>
<td>II: Unfavorable site, N0 and ≤5 cm</td>
<td>Bladder/Prostate Extremity Parameningeal Other (including: RP, perineal, perianal, intrathoracic, GI) Liver (nonbiliary)</td>
<td>≤5 cm</td>
<td>N0 or Nx</td>
<td>M0</td>
<td>80%</td>
</tr>
<tr>
<td>III: Unfavorable site, &gt;5 cm or node-positive</td>
<td>Same as Stage II</td>
<td>≤5 cm</td>
<td>N1</td>
<td>M0</td>
<td>68%</td>
</tr>
<tr>
<td>IV: Metastatic</td>
<td>All</td>
<td>Any size</td>
<td>Any N</td>
<td>M1</td>
<td>25%</td>
</tr>
</tbody>
</table>

T1, Confined to anatomic site of origin; T2, Extension and/or fixation to surrounding tissue; a, ≤5 cm in diameter; b, >5 cm in diameter; N0, Not clinically involved; N1, Clinically involved; Nx, Clinical status unknown; M0, No distant metastases; M1, Distant metastases.
Staging:
Remember the favorable sites by the mnemonic BONG

Danielle A. Cunningham, MD
Grouping

– Remember, depends on possible extent of surgical resection; the group is assigned at the time of initial diagnosis

• If a patient is deemed unresectable, has a great response to chemotherapy, and then has a gross total resection...this patient remains at Group 3

<table>
<thead>
<tr>
<th>TABLE 56.6: IRSG Grouping Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Group II</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Group III</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Group IV</td>
</tr>
</tbody>
</table>
Risk Stratification

• Pearls:
  – Know the intermediate risk, the rest will fall into place
    • Embryonal = Stage 2 or 3, Group 3
      – This means an unfavorable site with an incomplete resection
    • Alveolar = All stages and groups, apart from metastatic (4)

<p>| TABLE 56.7: Risk Stratification Based on Pre-Op Staging + Post-Op Grouping⁶ |
|-----------------------------------|-----------------------------------|</p>
<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Involved Groups</th>
</tr>
</thead>
</table>
| Low       | Favorable histology (embryonal) and
|           | – Favorable site (Stage I): Group I–III
|           | – Unfavorable site (Stage II–III): Groups I–II |
| Intermediate | – Favorable histology (embryonal), unfavorable site (Stage II–III): Group III
|           | – Unfavorable histology (alveolar), any Stage (I–III) or Group(I–III) |
| High      | Stage IV, Group IV |
Introduction to Treatment

This will vary based on risk group and protocol used.
Introduction to Treatment

1. Non-Morbid Surgery *(if this is not possible, a simple incisional biopsy will do; this tumor is radiosensitive so do not handicap the patient!)*
   - If possible: complete excision with 5 mm margins
   - Extremity RMS must have at least sentinel lymph node biopsy
   - Paratesticular RMS in boys > 10 years should have a retroperitoneal lymph node dissection
Delayed Primary Excision (DPE)

- The rational for DPE is:
  - For tumors that are unresectable at diagnosis, the chemotherapy will cause tumor shrinkage: 1) making it resectable 2) with the resection, allowing a lower dose of radiation
  - This was explored on COG D9803
    - In an attempt to potentially reduce the dose of RT given to patients with intermediate-risk RMS whose tumors were unresectable at diagnosis, select patients were treated with induction chemotherapy followed by DPE prior to RT.
    - Those who achieved gross total resection at the time of DPE were then eligible for reduced dose RT
      - 36 Gy if the tumor was completely resected
      - 41.4 Gy for microscopic residual
      - 50.4 Gy for those without DPE or with DPE in which gross residual disease remained postoperatively.
    - Local control following DPE and reduced dose RT was similar to historic results after higher doses of definitive RT.
COG D9803

Figure 1. Local control algorithm for COG D9803. Delayed primary excision (DPE), complete response (CR), partial response (PR) and radiation therapy (RT).
2) Chemotherapy

• Chemotherapy
  – **VAC** based; this will vary on protocol
    • Vincristine
    • Actinomycin-D
    • Cyclophosphamide
3) Radiation - Doses

<table>
<thead>
<tr>
<th>Clinical Group</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>I, Embryonal or FOX01 fusion negative</td>
<td>0 Gy</td>
</tr>
<tr>
<td>I, FOX01 fusion positive</td>
<td>36 Gy</td>
</tr>
<tr>
<td>II</td>
<td>36 Gy</td>
</tr>
<tr>
<td>III, &lt; 5 cm</td>
<td>50.4 Gy</td>
</tr>
<tr>
<td>III, &gt; 5 cm</td>
<td>59.4 Gy</td>
</tr>
</tbody>
</table>

Notes:

*Omission of radiation is only allowed for node negative patients

*A complete response (CR) will receive 36 Gy

*A cone-down is allowed if the dose exceeds 36 Gy; pre-chemotherapy volume will receive 36 Gy, post-chemotherapy volume will receive the higher dose

*A CR in the orbit will receive 45 Gy; otherwise 50.4 Gy
3) Radiation – Doses post DPE

<table>
<thead>
<tr>
<th>Clinical Group</th>
<th>Total Dose - Gy</th>
<th>post DPE - Dose Gy</th>
<th>Gross disease doses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>if no CR at Week 9**</td>
<td>if CR at Week 9**</td>
<td>if GTR post DPE with negative margin</td>
</tr>
<tr>
<td>I, FOXO1 +</td>
<td>36</td>
<td>36</td>
<td>N/A</td>
</tr>
<tr>
<td>II</td>
<td>36</td>
<td>36</td>
<td>N/A</td>
</tr>
<tr>
<td>III, ≤5cm*</td>
<td>50.4</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>III, &gt;5cm*</td>
<td>59.4</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

CR response doses
A positive margin will require slight dose escalation
Gross disease doses
3) Radiation - Target Volumes

- Radiation Target Volumes
  - GTV1
    - The volume is defined as disease prior to any surgical debulking or chemotherapy*
      - Post-operative radiation: tumor bed and any bone or soft tissue that was involved with the tumor prior to surgical resection
      - Definitive Radiation: tumor prior to any chemotherapy
  - CTV1
    - GTV + 1 cm
    - When lymph nodes are clinically or pathologically involved with tumor, the entire lymph node drainage chain should be included in the CTV.
  - PTV1
    - Minimum of 0.3 cm
3) Radiation - Target Volumes

- Radiation Target Volumes 2: these volumes are utilized when the prescription dose is higher than 36 Gy
  - GTV2
    - The volume is defined as disease after chemotherapy (this is the cone-down)
  - CTV2
    - GTV + 1 cm
  - PTV2
    - Minimum of 0.3 cm depending on immobilization
3) Radiation Timing

• Radiation Timing
  – Low and Intermediate Risk = Week 13
  – High Risk = Week 20

  – Patients with cord compression, visual loss, intracranial extension, cranial neuropathies = Day 0 per ARST 0431

  • However, in many cases emergent chemotherapy will relieve symptoms as quickly as radiation and delaying radiation should be assessed on a case by case basis
ARST 0331 – Low Risk Protocol

1. Biopsy/Surgery
2. VAC chemotherapy
3. XRT starts at week 13
4. VA chemotherapy
ARST 1431 – Intermediate Risk Protocol

1. Biopsy/Surgery

2. VAC chemotherapy (this study also investigates use of temsirolimus (an mTOR inhibitor))

3. XRT starts at week 13 (allowed for DPE)

4. Consolidation chemotherapy

October 16, 2021
ARST 0431– High Risk Protocol

- **Local control is achieved by radiation;** resection is rarely indicated

- **Week 1-6**
  - Vincristine/irinotecan

- **Week 7 to 19**
  - Vincristine/doxorubicin/cyclophosphamide alternating with etoposide/ifosfamide

- **Week 20 - 25**
  - **Radiation** with vincristine/irinotecan

- **Week 26 – 34**
  - Vincristine/doxorubicin/cyclophosphamide alternating with etoposide/ifosfamide

- **Week 38 - 46**
  - Vincristine/dactinomycin/cyclophosphamide

- **Week 47 – 62**
  - Vincristine/irinotecan
Management of Metastatic Disease in ARST 0431

• All radiation, primary site and metastatic disease, is given at week 20

• All metastatic sites will receive radiation regardless of their response

• Pulmonary Mets
  – 15 Gy in 10 fx whole lung irradiation (WLI), with a boost to any gross residual to 50.4 Gy
Prognosis - Event Free Survival (EFS)

• Low Risk EFS = 90%

• Intermediate Risk EFS = 70%

• High Risk EFS = Less than 30%
  – Remember, these are the metastatic patients
Follow - Up

• Year 1
  – MRI q3 months of primary site
  – CT Chest q3 months (with imaging of any metastatic sites)

• Year 2 -3
  – MRI q4 months of primary site
  – CT Chest q4 months (with imaging of any metastatic sites)

• Year 4 -5
  – MRI q6 months of primary site
  – CT Chest q6 months (with imaging of any metastatic sites)
Case
Case Presentation

• 4 year old boy who presented with swelling of his right upper eyelid
  – Parents noted a mass here a few days prior to presentation

• After initial infectious workup, MRI was ordered
Right Eye
Initial MRI

MRI showed a nonspecific mass anterior and superior to the right globe measuring 2cm
Case Presentation

• Incisional biopsy was performed with pathology returning for:
  – Rhabdomyosarcoma
  – Spindle cell variant (Embryonal), FOXO1 fusion negative

• PET CT negative apart from primary site
• A bone marrow biopsy is usually indicated; however, per ARST1431: patients with embryonal RMS who have non-invasive tumors that <5 cm without nodal disease, bone marrow biopsy is not indicated

• Stage: 1 (BONG)
• Group: 3 (Unresectable)
• Risk Group: Low
Case Presentation

- Treatment was started with 4 cycles induction VAC, local control with radiation, followed by 4 cycles VA (as per the low risk protocol)

- At time of simulation for XRT, there was complete resolution of the orbital mass

- We planned to treat the pre-chemotherapy tumor volume to 45 Gy in 25 fractions (orbital dose) using VMAT, starting with week 13 of chemotherapy
Radiation Simulation

- CT
- MRI with and without contrast
- Facemask
- Anesthesia was required (due to young age)

- Given the superficial location of the tumor, a 1 cm bolus was used
Radiation Plan

• What do you want to contour as **GTV**?
  – Pre-chemotherapy volume
Radiation Plan

• What is the CTV?
  – 1 cm expansion from the GTV, anatomically constrained

• What is the PTV?
  – Minimum of 0.3 cm, depending on immobilization

Simulation MR Scan
Radiation Plan in 3 Dimensions
17.10 **Organs at Risk for fractionated targets (not SBRT)**

The organs at risk (OAR) guidelines in this section are recommendations. If the recommended doses to the OAR are exceeded because of target volume coverage requirements or other conditions, an explanation should be included in the quality assurance documentation. In some cases, proton IMRT may be the preferred treatment method to meet these recommendations and the required target volume coverage guidelines. Normal tissue tolerance is the same for photons and protons (proton dose measured in CGE).

### 17.10.1 Organs at risk dose recommendations

<table>
<thead>
<tr>
<th>Organ</th>
<th>Volume (%)</th>
<th>Dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single organs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td>100%</td>
<td>45</td>
</tr>
<tr>
<td>Heart</td>
<td>100%</td>
<td>30</td>
</tr>
<tr>
<td>Liver</td>
<td>100%</td>
<td>23.4</td>
</tr>
<tr>
<td>Rectum</td>
<td>50%</td>
<td>30</td>
</tr>
<tr>
<td><strong>Optic chiasm</strong></td>
<td>100%</td>
<td>54</td>
</tr>
<tr>
<td><strong>Small Bowel</strong></td>
<td>50%</td>
<td>45</td>
</tr>
<tr>
<td><strong>Spinal Cord</strong></td>
<td>Any volume</td>
<td>45</td>
</tr>
<tr>
<td><strong>Paired organs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney (bilateral)</td>
<td>50%</td>
<td>24</td>
</tr>
<tr>
<td>Kidney (bilateral)</td>
<td>100%</td>
<td>14.4</td>
</tr>
<tr>
<td>Lung (bilateral)</td>
<td>20%</td>
<td>20</td>
</tr>
<tr>
<td><strong>Lung (bilateral)</strong></td>
<td>100%</td>
<td>15</td>
</tr>
<tr>
<td><strong>Optic nerve</strong></td>
<td>100%</td>
<td>54</td>
</tr>
<tr>
<td>Lens</td>
<td>100%</td>
<td>14.4</td>
</tr>
<tr>
<td>Lacrimal Gland/Cornea</td>
<td>100%</td>
<td>41.4</td>
</tr>
</tbody>
</table>
Plan Evaluation

Dose Volume Histogram

Dose (cGy)

Norm.Volume
Plan Evaluation

• Is the PTV adequately covered? Yes
  – 98% of PTV45 receives prescription dose

• Did we respect all dose constraints? Yes and No
  – The right lacrimal gland and right lens dose constraints were exceeded due to their location in the target volume. This will possibly lead to dry eyes, tearing, lens opacification with cataract formation
  – Right optic nerve received a max of 47 Gy, below constraint of 54 Gy
Side Effects

• **Acute side effects:**
  – Dry eye and possible redness of the eyelid
    • Given Aquaphor and artificial tears
  – Loss of eyelashes and eyebrows
    • They grow back to varying degrees

• **Late radiation side effects:**
  – Cataract formation, persistent dry eye, damage to the lacrimal gland and lacrimal duct, hypoplasia of the bony orbit, and risk of secondary radiation-induced malignancy.
Follow-ups

• MRI orbit and CT chest without evidence of disease

• His hair, eyelashes, and eyebrows grew back

• He maintains close follow-up with ophthalmology
References

• Gupta, Abhda. A Randomized Phase 3 Study of Vincristine, Dactinomycin, Cyclophosphamide (VAC) Alternating with Vincristine and Irinotecan (VI) Versus VAC/VI Plus Temsirolimus (TORI, Torisel, NSC# 683864) in Patients with Intermediate Risk (IR) Rhabdomyosarcoma (RMS)
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• Walterhouse, David. Vincristine, Dactinomycin, and Lower Doses of Cyclophosphamide With or Without Radiation Therapy for Patients with Newly Diagnosed Low-Risk Embryonal/Botryoid/Spindle Cell Rhabdomyosarcoma
• Weigel, Brenda. Intensive Multi-Agent Therapy, Including Dose-Compressed Cycles of Ifosfamide/Etoposide (IE) and Vincristine/Doxorubicin/Cyclophosphamide (VDC) for Patients with High-Risk Rhabdomyosarcoma

Please provide feedback regarding this case or other ARROcases to arrocase@gmail.com