PEDIATRIC CANCERS AND THE ROLE OF PHYSICAL THERAPY ALONG THE CONTINUUM OF CARE

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OBJECTIVES

- Identify and describe common pediatric oncology diagnoses.
- Recognize the associated side effects of medical treatments for pediatric cancers and their impact on function.
- Develop and implement effective physical therapy examinations, treatment strategies, and overall plan(s) of care for pediatric patients in all stages of cancer treatment.
- Discuss the differences between pediatric and adult cancers.

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GENERAL OVERVIEW

Pediatric Cancers

ADULT VERSUS PEDIATRIC CANCERS

- Pediatric cancers are not strongly linked to lifestyle factors
- Less health co-morbidities lend to improved response and tolerance of treatment
- Cancer treatment can have long term side effects
- More inpatient admissions

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COMMON PEDIATRIC CANCERS

- Leukemia
- Brain and spinal cord tumors
- Neuroblastoma
- Wilms tumor
- Lymphoma (including both Hodgkin and Non Hodgkin)
- Rhabdomyosarcoma
- Retinoblastoma
- Bone cancer (including osteosarcoma and Ewing sarcoma)

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KEY STATISTICS

- Pediatric cancers make up < 1% of all cancers diagnosed each year
- An estimated 10,590 new cancer cases will be diagnosed among children 0 to 14 years of age in the US in 2018.
- Cancer is the second-leading cause of death among children ages 1-14 years (after accidents), accounting for 13% of deaths in 2015.

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INCIDENCE RATES

American Cancer Society. Cancer Facts & Figures 2018. Atlanta: American Cancer Society; 2018.

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ETIOLOGY

- Inherited familial syndromes
  - Neurofibromatosis type 1
  - Li-Fraumeni syndrome
- Genetic syndromes
  - Down Syndrome
- Germline mutations
- Environmental factors
  - Ionizing radiation
- Lifestyle factors
  - Not typically a factor in pediatric cases

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GENERALIZED SIGNS AND SYMPTOMS

- Unusual mass or swelling
- Paleness
- Loss of energy
- Increase in bleeding or bruising
- Persistent, localized pain or limping
- Prolonged/unexplained fever
- Frequent headaches often associated with vomiting
- Sudden eye or vision changes
- Sudden unexplained weight loss

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GENERAL DIAGNOSTIC TESTS

- Medical history and physical exam
- Blood tests
- Bone marrow aspiration and biopsy
- Lumbar puncture
- Biopsy
- Chest x-ray
- Computed tomography (CT) or positron emission tomography (PET) scan
- Magnetic resonance imaging (MRI)
- Ultrasound

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STAGING

- Currently no national system for pediatrics

- Staging systems vary by:
  - Diagnosis
  - Trial group/current protocol

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MEDICAL INTERVENTIONS

- Chemotherapy
- Radiation therapy
- Surgery
- Steroids

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CHEMOTHERAPY

- Cytotoxic medications used to kill cancerous cells by:
  - Killing cancer cells
  - Stopping cancer cells from dividing
- Most common methods of administration:
  - Oral
  - Intravenous
  - Intrathecal
- Malignant cancers receive multiple chemotherapy agents via individualized road maps

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COMMON TYPES OF CHEMOTHERAPY AGENTS

Chemotherapy Agent	Possible Side Effects	Common Diagnoses
Vincristine	Hair loss, **peripheral neuropathy**, constipation, low blood counts, nausea, vomiting, mouth sores, diarrhea, loss of appetite, taste changes, abdominal cramping	Acute leukemia, Hodgkin's/non-Hodgkin's lymphoma, neuroblastoma, rhabdomyosarcoma, Ewing's sarcoma, Wilms' tumor, multiple myeloma, chronic leukemias, thyroid cancers, brain tumors, and some blood disorders
Cisplatin	Low blood counts, nausea, vomiting, kidney toxicity, low magnesium/potassium/calcium, **peripheral neuropathy**, high frequency hearing loss, loss of appetite, taste changes, liver dysfunction, hair loss, changes in fertility	Hodgkin's/non-Hodgkin's lymphoma, neuroblastoma, sarcomas
Etoposide	**Low blood counts, low platelet counts, hypotension, loss of fertility, nausea, vomiting, hair loss, mouth sores, diarrhea, poor appetite, nerve damage**	Hodgkin's and non-Hodgkin's lymphoma, Wilm's tumor, rhabdomyosarcoma, Ewing's sarcoma, neuroblastoma, brain tumors, and can be used for conditioning for bone marrow transplant
High dose methotrexate	**Low blood counts, mouth sores, poor appetite, nausea, vomiting, kidney toxicity**, kidney failure, skin rash, diarrhea, hair loss, eye irritation, liver problems, radiation recall, loss of fertility	Acute lymphoblastic leukemia, sarcomas, non-Hodgkin's lymphoma, and cutaneous T cell lymphoma
Doxorubicin	**Heart damage, fatigue, nausea, vomiting, mouth sores, bone marrow suppression**	Soft tissue and bone sarcomas, acute lymphoblastic leukemia, acute myeloid leukemia, Hodgkin lymphoma
Ifosfamide	Damage to lining of bladder, mouth sores, nausea, vomiting, **nerve damage**, blurred vision, hair loss	Soft tissue and bone sarcoma

CHEMOTHERAPY SIDE EFFECTS

- Nausea/vomiting
- Fatigue
- Fever
- Pain
- Hearing loss
- Anemia/neutropenia
- Bruising/bleeding
- Diarrhea or constipation
- Nerve/muscle effects
- Secondary malignancies
- Hair loss
- Mouth sores
- Weight loss
- Infection
- Changes in appetite

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RADIATION THERAPY

- Use of high energy particles or waves to destroy cancer cells by inhibiting cell growth and division
- Method of administration depends on type and stage of cancer
  - External
  - Internal
  - Systemic

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TYPES OF RADIATION

X-ray/photon

- Total brain irrigation
- Deposit energy in small packets along their path through the tissue
- Can damage healthy tissue

Proton

- Targets tumor at higher intensity
- Depth of energy is released and can be controlled
- Fewer short term and long term side effects
- Decreases risk of secondary malignancies

DOSE DISTRIBUTION

Fowler JF. What can we expect from dose escalation using proton beams? Clin Oncol. 2003;15(1):S10-S15.

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RADIATION THERAPY GENERAL SIDE EFFECTS

- Fatigue
- Hair Loss
- Integumentary changes
- Immunosuppression
- Secondary malignancies

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SURGERY

- Curative
  - Gross total resection
  - Clear margins
- Palliative
  - Relieve pain
  - Minimize symptoms
  - Improve quality of life

TYPES OF SURGERIES

- Biopsy
- Gross total resection versus partial resection
- Reconstruction
- Limb salvage
- Amputation

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SURGICAL SIDE EFFECTS

- Pain
- Fatigue
- Appetite loss
- Integumentary changes
- Numbness
- Bleeding
- Infection
- Physical impairments
- Cognitive impairments

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STEROIDS

- Corticosteroids are man-made drugs that work like cortisol, a natural hormone in your body.
- Prescribed as part of treatment or as a supportive measure
- Common corticosteroids used in pediatric cancer treatment:
  - Dexamethasone
  - Prednisone

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STEROID SIDE EFFECTS

- Increased appetite
- Weight gain
- Muscle weakness
- Mood swings
- Nausea
- Insomnia
- High glucose levels
- High blood pressure
- Avascular necrosis (AVN)
- Hearing loss
- Immunosuppression
- Gastrointestinal issues

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PEDIATRIC CANCER PROGNOSIS

- The 5-year relative survival for the most recent time period (2007-2013) is 83%, although rates vary considerably depending on cancer type, patient age, and other characteristics.
- Depends on several factors including:
  - Type of tumor
  - Location of tumor
  - Grade of tumor
  - Staging
  - Speed of growth
  - Treatment options
  - Age of child
- Childhood cancer survivors can experience late and long term effects from treatment in a variety of body systems.

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SURVIVAL RATES

American Cancer Society. Cancer Facts & Figures 2018. Atlanta: American Cancer Society; 2018.

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BONE MARROW, STEM CELL, AND CORD BLOOD TRANSPLANTS

- Healthy marrow or stem cells are infused into pt's blood stream
- Goal of transplant is engraftment
- Indications
  - Patients with relapsed ALL and AML
  - Patients with life threatening disease
  - Patients with Neuroblastoma
  - Some patients with brain tumors

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BONE MARROW, STEM CELL, AND CORD BLOOD TRANSPLANTS

- Types of Transplant
  - Bone Marrow
  - Stem Cells
  - Umbilical Cord Blood
- Source of cells
  - Allogenic - Donor
  - Autogenic - Self
  - Syngenic - Identical twin

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TRANSPLANT PROCESS

- Pre-transplant conditioning
  - High doses of chemo and or radiation
- Transplant
  - Cells are administered
- Post-transplant
  - Await engraftment
  - Usually 12-17 days

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BONE MARROW AND STEM CELL TRANSPLANT – SIDE EFFECTS

- Graft vs. Host Disease (GVHD)
- Mucositis
- Nausea/Vomiting
- Venous Occlusive Disease (VOD)
- Steroid induced myopathy
- Sterility
- Cardiac and pulmonary disease
- High risk of life threatening infection
- Secondary malignancies

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SOLID TUMORS

COMMON DIAGNOSES

- Osteosarcoma
- Ewing's Sarcoma
- Rhabdomyosarcoma
- Neuroblastoma

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OSTEOSARCOMA

- Tumor cells arise from osteoblast cells and primarily affect the ends of the long bones
- Most common malignant bone tumor in children and adolescents
  - ~ 400 new pediatric cases each year in the United States
  - ~ 2% of childhood cancers
- Common sites:
  - Distal femur
  - Proximal tibia
  - Proximal humerus

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OSTEOSARCOMA SIGNS AND SYMPTOMS

- Pain
  - Stiffness or tenderness
  - Progressively worse over time
  - Wakes from sleep
- Swelling
- Palpable mass in arm or leg
- Difficulty walking or limp
- Fracture
- Fatigue
- Weight loss
- Anemia

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OSTEOSARCOMA STAGING

- Simplified
  - Local
    - Resectable
    - Non-resectable
  - Metastatic
- Musculoskeletal Tumor Society (MSTS) staging system
  - Grade (G)
  - Extent of primary tumor (T)
  - Metastases (M)
- TNM staging system
  - (T) Tumor
  - (N) Nodes
  - (M) Metastasized
  - (G) Grade

Stage	Grade	Tumor	Metastasis
IA	G1	T1	M0
IB	G1	T2	M0
IIA	G2	T1	M0
IIB	G2	T2	M0
III	G1 or G2	T1 orT2	M1

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OSTEOSARCOMA TREATMENT

- Chemotherapy: Total 6 cycles
  - Neoadjuvant: Prior to surgery or radiation
    - 2 cycles
  - Adjuvant: Continues after surgery/radiation
  - Common chemotherapy agents:
    - Methotrexate
    - Doxorubicin
    - Cisplatin
    - Ifosfamide
    - Etoposide
- Surgery
  - Goal: to remove all cancer cells (negative margins)
  - Limb Salvage
  - Amputation
  - Time frame of surgery: Week 11
- Radiation
  - Not very sensitive to radiation
  - Used when positive margins left following surgery
  - Symptom control in recurrent tumors

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OSTEOSARCOMA PROGNOSIS

- Positive Prognostic Factors
  - Younger age
  - Female
  - Distal primary tumor site
  - Complete tumor resection
  - Good tumor necrosis following chemotherapy
- 5 year survival rate
  - Localized: 60-80%
  - Metastatic: 15-30%
    - Improved to ~ 40% if only metastasis is to lungs
    - Improved survival if tumor and all metastases can be surgically removed

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EWING'S SARCOMA

- Malignant small, round, blue cell tumor starting in the bones or surrounding soft tissue
- Second most common malignant bone tumor in children and adolescents
  - ~ 200 new cases each year in the United States
  - ~ 1% of childhood cancers
- Common Sites:
  - Pelvis
  - Chest wall (ribs and scapula)
  - Legs (middle of long bones)

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EWING'S SARCOMA SIGNS AND SYMPTOMS

- Pain
  - Stiffness or tenderness
  - Progressively worse over time
  - Wakes from sleep
- Swelling
- Palpable mass
- Difficulty walking or limp
- Fracture
- Fatigue
- Weight loss
- Anemia

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EWING'S SARCOMA STAGING

- Simplified
  - Local
  - Metastatic
- American Joint Committee on Cancer (AJCC) staging system – TNMG
  - (T) Tumor
    - T0: No evidence of primary tumor
    - T1: Tumor is no more than 8 cm across
    - T2: Tumor is larger than 8 cm across
    - T3: Tumor is in more than one site in the same bone
  - (N) Nodes
    - N0: No spread to nearby lymph nodes
    - N1: Spread to nearby lymph nodes
  - (M) Metastasis
    - M0: No metastasis
    - M1a: Metastasis to lungs only
    - M1b: Metastasis to other parts of the body
  - (G) Grade
    - GX: Grade can not be assessed
    - G1: Low grade
    - G2-G3: High grade
    - All Ewing tumors are considered G3

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EWING'S SARCOMA TREATMENT

- Chemotherapy: Total of 6 cycles
  - Each cycle includes:
    - Vincristine, doxorubicin, cyclophosphamide
    - Ifosfamide, etoposide
  - Neoadjuvant: Prior to surgery or radiation
    - 3 cycles
  - Adjuvant: Continues after surgery/radiation
- Surgery
  - Goal: to remove all cancer cells (negative margins)
  - Depends on size and location of tumor
    - Arms/Legs: limb sparing versus amputation
    - Proximal tumors: more complicated
  - Time frame of surgery:
    - Following 3 cycles of chemotherapy/Week 13
- Radiation
  - Ewing's tumors are very sensitive to radiation
  - Used as primary local control or in conjunction with surgery

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EWING'S SARCOMA PROGNOSIS

- Positive Prognostic Factors
  - Smaller tumor size
  - Distal tumor site (arm/leg versus chest wall or pelvis)
  - Tumor response to chemotherapy
  - Younger age (< 10 years old)
- 5 year survival rate
  - Localized: 70%
  - Metastatic: 30%

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RHABDOMYOSARCOMA (RMS)

- Aggressive tumor that develops from skeletal muscle cells that have failed to fully differentiate
  - Small, round, blue cell tumor
- Incidence: 400-500 new cases each year in United States
  - ~ 3% of childhood cancers
  - More common in males
  - More common in children < 10 years old
- Embryonal Rhabdomyosarcoma (ERMS)
  - Common in children 0-5 years old
  - Common in head/neck and urogenital tract
- Alveolar Rhabdomyosarcoma (ARMS)
  - Effects all age groups equally
  - Common in large muscles of trunk arms and legs

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RHABDOMYOSARCOMA SIGNS AND SYMPTOMS

- Depends on location of tumor
  - Eye: vision, eye bulging, oculomotor control
  - Sinuses: earache/headache, nosebleeds, congestion
  - Urogenital: bleeding, painful or difficulty with voiding or bowel movement
  - Abdomen/pelvis: vomiting, pain, constipation
- Lump or swelling
- Bone pain
- Weakness
- Weight loss

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RHABDOMYOSARCOMA STAGING

- 3 part staging:
  - TNM staging system
    - (T) Tumor
    - (N) Nodes
    - (M) Metastasized
    - Above factors combined to determine stage (1-4)
  - Clinical Group: I-IV
    - Based on extent of disease and initial tumor resection
  - PAX/FOX01 gene present or absent on tumor cells
- Risk Group:
  - Determined based on above 3 factors
  - Risk group determines treatment plan
  - Low, Intermediate, High

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RHABDOMYOSARCOMA TREATMENT

- Surgery
  - Typically first step in treatment (based on location, function or metastatic disease)
- Chemotherapy
  - Low Risk
    - VA: vincristine and dactinomycin
  - Intermediate Risk:
    - VAC: vincristine, dactinomycin, and cyclophosphamide
    - VAC/VI; vincristine, dactinomycin, and cyclophosphamide, alternating with vincristine and irinotecan
  - High Risk:
    - VAC or clinical trials
- Radiation
  - Typically used when some of the primary tumor is present after surgery
  - Used if resection would result in loss of vital organ or dysfunction

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RHABDOMYOSARCOMA PROGNOSIS

- 5 year survival rate
  - Low risk: 70-90%
  - Intermediate risk: 50-70%
  - High risk: 20-30%
- Positive prognostic factors
  - Age: 1-9 years old
  - Tumor size < 5cm
  - Gross total resection with negative margins
  - Absence of PAX/FOX01 gene

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NEUROBLASTOMA

- Cancer that start in neuroblasts of the sympathetic nervous system
- Most common cancer in infants
  - ~ 6% of all childhood cancers
  - ~ 800 new cases each year in the United States
  - 90% of cases diagnosed prior to 5 years of age.

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NEUROBLASTOMA SIGNS AND SYMPTOMS

- Lump/swelling in abdomen or neck
- Swelling of the legs or upper chest, neck and face
- Enlarged belly
- Problems breathing or swallowing
- Weight loss
- Complaining about feeling full
- Problems with bowel movements or urinating
- Pain in bones
- Lumps or bumps in the skin that may appear blue
- Problems being able to feel or move parts of the body
- Opsoclonus-myoclonus-ataxia syndrome

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NEUROBLASTOMA STAGING

- International Neurobalstoma Risk Group Staging System (INRGSS)
  - Uses results from imaging tests
  - Can be determined prior to start of treatment
  - 4 stages
    - L1, L2, M, MS
- International Neuroblastoma Staging System (INSS)
  - Uses results from tumor resection to determine stage
- Children's Oncology Group (COG) risk groups
  - Low risk
  - Intermediate risk
  - High risk:

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NEUROBLASTOMA TREATMENT

- Treatment plan based on risk group
- Surgery
  - Biopsy
  - Resection if possible
- Chemotherapy
  - Used prior to and following surgery
- Radiation
  - Not a common intervention for neuroblastoma
  - Used in high risk group following stem cell transplant or for symptom management and to treat life threatening symptoms
- High dose chemotherapy and stem cell transplant (SCT)
  - High risk group
  - Tandem SCT
  - Used to repair bone marrow from intense chemotherapy treatment
- Immunotherapy
  - Monoclonal antibodies injected into the body to seek out and attach to cancer cells
- MIBG
  - Highly radioactive from injected into the blood and delivers local radiation to neuroblastoma cells
  - Requires hospital admission in special environment

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NEUROBLASTOMA PROGNOSIS

- Positive prognostic factors
  - Younger age (< 12-18 months)
  - Favorable tumor histology
  - Low DNA index
  - Absence of MCYN gene amplifications
  - No chromosome changes to tumor cells
  - Presence of neurotrophin receptors
- 5 year survival rate
  - Low risk: 95%
  - Intermediate risk: 90-95%
  - High risk: 40-50%

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SURGICAL MANAGEMENT OF SOLID TUMORS IN THE EXTREMITIES

- Limb salvage
  - Endoprosthetic placement
  - Vascularized autologous bone graft
  - Allograft
- Amputation
  - Upper and lower extremity options
  - Rotationplasty

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LIQUID TUMORS

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COMMON DIAGNOSES

- Leukemia
- Lymphoma

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LEUKEMIA

- Cancer of the blood and bone marrow
- Cancer cells divide rapidly and live longer than healthy cells so take over the space leaving little to no room for healthy WBC, RBC, and platelets
- Incidence
  - Most common type of pediatric cancer
  - Accounts for 29% of all childhood cancers

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LEUKEMIA SIGNS AND SYMPTOMS

- Fever and unexplained infection
- Fatigue and generalized weakness
- Bruising and bleeding (petechiae)
- Bone and/or joint pain
- Abdominal pain due to enlarged liver or spleen
- Swollen lymph nodes
- Decreased appetite/weight loss

www.healio.com

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LEUKEMIA

- Types of Leukemia
  - Acute Lymphoblastic Leukemia (ALL)
    - T-Cell
    - B-Cell
  - Acute Myeloid Leukemia (AML)
- Classification - Acute versus Chronic
  - Acute – blast cells
  - Chronic – mature/ abnormal cells

ACUTE LYMPHOBLASTIC LEUKEMIA (ALL)

- B-Cell – 85%
  - Early Pre-B Cell
  - Pre-B Cell
  - B-Cell (Burkitt's Lymphoma)
- T-Cell – 15%
- Peak age for diagnosis is 2 – 4 years old
- Incidence - accounts for 80% of pediatric leukemia diagnoses

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ALL STAGING

Risk Group	Age at Diagnosis	Criteria
Standard Risk (SR)	1 – 9 years old	White Blood Cell (WBC) Count at Diagnosis < 50,000/µL
High Risk	Less than 1 year old Greater than 10 years old	White Blood Cell (WBC) Count at Diagnosis ≥ 50,000/µL
Very High Risk	Less than 1 year old with specific cyto-gentics	Children with slow response to treatment Children with signs of leukemia after the first 4 weeks of treatment

*Children with T-Cell ALL are classified in a higher risk group

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ALL TREATMENT

- Chemotherapy
- Radiation
- Transplant
  - Relapsed disease
- Chimeric Antigen Receptor Therapy (CAR-T)

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ALL PHASES OF CHEMOTHERAPY TREATMENT

	ALL - Standard Risk	ALL - High Risk
Induction	~ 1 month	~ 1 month
Consolidation	~1-2 months	~ 2 months
Interim Maintenance	~ 1-2 months	~ 2 months
Delayed Intensification	~ 2 months	~ 2 months
Maintenance	End of DI until ~ 2 years from start of therapy	End of DI until ~ 2 years from start of therapy

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ALL RADIATION THERAPY

- A minority of children with ALL require radiation therapy
- Possible indications
  - ALL that has spread to the brain, spinal cord or testicles
  - In preparation for bone marrow transplant
- Timing of radiation is variable

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CHIMERIC ANTIGEN RECEPTOR THERAPY (CAR-T)

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CAR-T OVERVIEW

- Targeted immunotherapy that genetically modifies a patient's T-cells so they will attack certain proteins on the surface of cancer cells
- Goal is proliferation and persistence of engineered T cells
- Indications:
  - Relapsed or refractory B-cell ALL
  - B-cell non Hodgkin's lymphoma
- Types
  - CAR-T 19 – targets CD 19 on cancer cell
  - Other receptor numbers are currently being investigated

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CAR-T PROCESS

- T-Cell harvest from patient through leukophoresis
  - Cells are manufactured in the lab with vector
  - During this time the patient undergoes bridging chemotherapy
- Infusion Process
  - Lymphodepleting chemotherapy for a week
  - Preinfusion studies completed (bone marrow aspirate and biopsy, diagnostic lumbar pucture)
  - Infusion of CAR-T Cells
- Ongoing Monitoring
  - Diagnostic testing at day 28 and then every 3 months for the first year
  - Positive idicators
    - CAR-T cells in peripheral blood, bone marrow, and CSF
    - Lack of cancer cells
    - Lack of B-Cells

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CAR-T

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CAR-T SIDE EFFECTS

- Cytokine Release Syndrome (CRS): systemic inflammatory response
  - Common Side Effects - High fever, Myalgias, Headaches, Nausea, and Fatigue
  - More Serious Side Effects – Hypotension, Vascular leak leading to respiratory compromise, Renal insufficiency, and Coagulopathy
- Fever
- Infection
- B-Cell aplasia
- Neurological side effects
  - Headaches
  - Encephalopathy
  - Seizures

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ALL PROGNOSIS

- Positive prognostic factors
  - Greater than 1 year old and less than 10 years old at diagnosis
  - WBC less than 50,000/µL at diagnosis
  - No CNS involvement at diagnosis
  - Cyto-genetics testing (ex Philadelphia chromosome negative indicator)
  - Initial response to treatment
- 5 year survival rate - 91%

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ACUTE MYELOID LEUKEMIA (AML)

- Types
  - M0 – M7 based on cell type as determined by BMA at diagnosis
- Peak ages of diagnosis are 0-2 years old and adolescence
- Staging – high risk if do not achieve remission after induction or AML is relapsed
- Incidence - accounts for 20% of all pediatric leukemia diagnoses

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AML TREATMENT

- Chemotherapy
- Monoclonal Antibody Therapy
- Transplant
  - Patients with a sibling match
  - Patients with relapsed disease
  - Patients with unfavorable cyto-genetics

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AML PHASES OF CHEMOTHERAPY TREATMENT

- Induction
  - ~1 month long
  - Repeated every 10 days to 2 week until bone marrow is leukemia free, usually 2-3 cycles
- Consolidation (Intensification)
  - Typically 3 cycles, each 28 days long

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MONOCLONAL ANTIBODY THERAPY

- Antibodies are used to deliver drugs and toxins to cancer cells
- Antibodies attaches to a protein found on the surface of many AML cells
- Used in combination with chemotherapy to improve the long-term survival

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MONOCLONAL ANTIBODY THERAPY SIDE EFFECTS

- Low blood counts
- Nausea
- Vomiting
- Headache
- Loss of appetite
- Fever and chills (most common with first dose)
- Fatigue
- Venous Occlusive Disease (VOD)

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AML PROGNOSIS

- Positive prognostic factors:
  - Greater than 1 year old at diagnosis and less than 10 years old at diagnosis
  - WBC less than **10,000**/µL at diagnosis
  - Cyto-genetics testing
  - Initial response to treatment
  - Lower BMI
- 5 year survival rate - 65%

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LYMPHOMA

- Cancer of the Lymphatic System
  - Can present as solid tumors of lymph nodes
- Types
  - Hodgkin Lymphoma
  - Non-Hodgkin Lymphoma
- Incidence
  - 3rd most common type of childhood cancer
  - 8% of all childhood cancers
  - More common in boys than girls

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LYMPHOMA SIGNS AND SYMPTOMS

- Swelling of lymph nodes
- Mediastinal mass
- Difficulty breathing
- Weight loss
- Night sweats
- Fatigue
- Fever

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HODGKIN LYMPHOMA

- Diagnosed based on presence of Reed-Sternberg Cells
- Peak age of diagnosis is 15-19 years old
- Incidence - 10% of all pediatric lymphoma diagnoses

HODGKIN LYMPHOMA STAGING

https://www.lls.org/lymphoma/hodgkin-lymphoma/diagnosis/hodgkin-lymphoma-staging

HODGKIN LYMPHOMA TREATMENT

- Chemotherapy
- Radiation
- Transplant

HODGKIN LYMPHOMA PROGNOSIS

- Positive Prognostic Factors
  - Lack of metastasis
  - Lack of B symptoms
    - unexplained fever
    - drenching night sweats
    - unexpected weight loss
  - Response to treatment
- 5 year survival rate - 98%

NON-HODGKIN LYMPHOMA

- Types
  - Small B-Cell Lymphoma (Burkitt's Lymphoma)
  - Lymphoblasitc Lymphoma (T-Cell Lymphoma)
  - Large cell Lymphoma
- Peak age of diagnosis is adolescence
- Incidence - 90% of all pediatric lymphoma diagnoses

NON-HODGKIN LYMPHOMA STAGING

Stage	
Stage I	Cancer is in one group of lymph nodes
Stage II	Tumor present in two or more lymph node areas on the same side of the diaphragm
Stage III	Tumor on both sides of the diaphragm
Stage IV	Tumor has spread from original location to bone marrow or central nervous system (brain or spinal fluid)

NON-HODGKIN LYMPHOMA TREATMENT

- Chemotherapy
- Surgery (Burkitt's)
- Monoclonal Antibody Therapy
- Transplant

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NON-HODGKIN LYMPHOMA PROGNOSIS

- Positive Prognostic Factors
  - Lack of metastasis
  - Lack of B symptoms
    - unexplained fever
    - drenching night sweats
    - unexpected weight loss
  - Response to treatment
- 5 year survival rate –91%

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BRAIN TUMORS

CLASSIFICATION OF BRAIN TUMORS

CLASSIFICATION OF BRAIN TUMORS

Primary
- Originate from normal cells within the brain
- Name includes cell of origin with or without location
- Benign or malignant

Secondary (Metastatic)
- Originate from cells outside of the central nervous system (CNS)
- Always malignant

CLASSIFICATION OF BRAIN TUMORS

Benign
- Typical of the cell of origin
- Decreased mitosis
- Slow growing/low grade
- Localized
- Well defined borders

- **Malignant**
- Cell of origin with greater differentiation
- Increased mitosis
- Fast growing/high grade
- Invade surrounding brain tissues
- Metastasize outside of the CNS

WORLD HEALTH ORGANIZATION (WHO) BRAIN TUMOR GRADES

Grade	Characteristics	Tumor Types
Low Grade	Grade I	•Least malignant (benign) •Possibly curable via surgery alone •Non-infiltrative •Long-term survival •Slow growing
	Grade II	•Relatively slow growing •Somewhat infiltrative •May recur as higher grade
High Grade	Grade III	•Malignant •Infiltrative •Tend to recur as higher grade
	Grade IV	•Most malignant •Rapid growth, aggressive •Widely infiltrative •Rapid recurrence •Necrosis prone

CLINICAL PRESENTATION

GENERALIZING SYMPTOMS

- Increased intracranial pressure (ICP)
  - Headache, nausea, vomiting, fatigue
  - Decreased upgaze, sixth cranial nerve palsies, papilledema
  - Infants: macrocephaly, failure to thrive, developmental delay
- Ataxia
- "Flu-like" symptoms
- Cranial nerve deficits
- Cognitive deficits or changes in school performance
- Mental status changes
- Seizures

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LOCALIZING SYMPTOMS

Jain, V. Brain Tumor. Slide Share website. https://www.slideshare.net/jvcom001/brain-tumor-68206369. November 4, 2016. Accessed November 1, 2018.

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TYPES OF TUMORS

COMMON DIAGNOSES

- Astrocytoma
- Medulloblastoma
- Ependymoma
- Brain stem glioma

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TYPES OF TUMORS

Brain Tumors. Children's Hospital of Wisconsin website https://www.chw.org/medical-care/mmcc-fund-center/conditions/oncology/brain-tumors. Accessed November 1, 2018.

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ASTROCYTOMA

- Incidence:
  - 35% of childhood brain tumors
  - 80% are low grade
  - Most common in children 5-8 years old
- Location:
  - Can occur anywhere in the central nervous system (CNS)

Cerebellar Astrocytomas. Clinical Gate website https://clinicalgate.com/cerebllar-astrocytomas/. March 26, 2015. Accessed November 1, 2018.

ASTROCYTOMA GRADING SCALE

	Grade	Histology
Low Grade	I	Juvenile pilocytic astrocytoma (JPA)
	II	Diffuse astrocytoma
High Grade	III	Anaplastic astrocytoma
	IV	Glioblastoma multiforme (GBM)

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ASTROCYTOMA TREATMENT

- Depends on location and grade of tumor
  - Low grade
    - Surgery is primary therapy
    - Management of residual tumor:
      - Observation
      - Re-resection
      - Radiation therapy
  - High grade
    - Surgery
    - Radiation therapy

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ASTROCYTOMA PROGNOSIS

- Prognostic factors
  - Low grade
    - Young age
    - Subtotal resection
- 5 year survival rates
  - Low grade
    - 97% for pilocytic
    - 80-85% for diffuse
  - High grade
    - 25% for anaplastic
    - 20% for GBM

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MEDULLOBLASTOMA

- Incidence:
  - 18-20% of primary CNS tumors
  - >70% occur in children less than 10 years old
  - Slightly more common in males
- Location:
  - Cerebellum

Guillard, F. Medulloblastoma. Radiopaedia website https://radiopaedia.org/articles/medulloblastoma. Accessed November 1, 2018.

MEDULLOBLASTOMA STAGING

	Standard Risk	High Risk
Age	>/= 3 years old	< 3 years old
Location	Cerebellum	Supratentorial
Residual Tumor	< 1.5 cm²	>/= 1.5 cm²
Metastases	No	Yes

Slide courtesy of Cindy Schwan

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MEDULLOBLASTOMA TREATMENT

- Surgery
- Radiation therapy
- Chemotherapy
- Bone/stem cell transplant

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MEDULLOBLASTOMA PROGNOSIS

- Prognostic factors
  - Subtotal resection
  - Patient age: < 3 years old
  - Location: supratentorial
  - Metastasis
- 5 year survival rates
  - Standard Risk: 70-80%
  - High Risk: 60-65%
  - Infants: 30-50%

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EPENDYMOMA

- Incidence:
  - 9-10% of childhood brain tumors
- Location:
  - Supratentorium
  - Infratentorium
  - Spinal

Ependymoma. Pediatric Oncology Education Materials website http://www.pedsoncologyeducation.com/ependymoma_location.asp. Accessed November 1, 2018.

EPENDYMOMA TREATMENT

- Surgery – aggressive resection
- Radiation therapy
- Chemotherapy
- Observation – in rare cases

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EPENDYMOMA PROGNOSIS

- Prognostic factors
  - Subtotal resection
  - Histology: anaplastic
  - Metastasis
  - Younger age at diagnosis
  - Location
- 5 year survival rates
  - Birth to 19: 75%

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BRAIN STEM GLIOMA

- Incidence:
  - 10% of pediatric brain tumors
- Location:
  - 80% occur in the pons
- Types:
  - Diffuse intrinsic
  - Focal

Brain Stem Glioma. Brain Tumour Foundation of Canada website https://www.braintumour.ca/4884/brainstem-glioma. Accessed November 1, 2018.

BRAIN STEM GLIOMA

- Based on type:
  - Focal:
    - Observation (with or without cerebrospinal fluid diversion)
    - Surgical resection
    - Adjuvant therapy in the form of radiation therapy or chemotherapy in select circumstances
  - Diffuse intrinsic:
    - Radiation therapy – standard of care

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BRAIN STEM GLIOMA PROGNOSIS

- Prognostic factors
  - Type: Diffuse intrinsic
  - Location in pons
  - Age: > 3 years of age with diffuse intrinsic
- 5 year survival rates
  - Based on location:
    - Focal: >90% 5 year survival rate
    - Pons: median survival rate < 1 year

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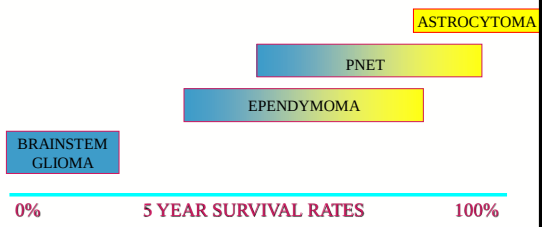
PROGNOSIS



Slide courtesy of Cindy Schmus

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PHYSICAL THERAPY MANAGEMENT

ADULT VERSUS PEDIATRIC CONSIDERATIONS

- Children are not small adults
  - Children react differently to treatments
  - Children heal more quickly
  - Children are undergoing periods of rapid growth and development
- Children will be active if they feel good
- Family centered care

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GENERAL CONSIDERATIONS

Patient
- Medical status
- Cognitive status
- Chronological/ developmental age
- Level of coping

Family
- Level of coping
- Dynamics
- Resources/supports

MEDICAL CONSIDERATIONS

- Lab values
- Treatment effects
- Lines and tubes
- General anesthesia effects

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AGE RELATED CONSIDERATIONS

- Baseline developmental abilities
- Use of preferred play and leisure activities

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EXAMINATION

History, Review of Systems, Tests and Measure

HISTORY

Objective
- Medical history
- Imaging
- Operative reports
- Medications
- Red flags

Subjective
- Social
- Developmental
- Home set up
- Equipment
- Schooling/Daycare

PAIN

- Pain Scales
  - Numerical rating scale
    - > 8 years of age
  - FLACC
    - 2 months to 7 years
  - Wong-Baker Faces
    - 3 years and up
- Consider
  - Impact of pain on other assessment areas
  - Impact of arousal level/cognition on ability to communicate pain
  - Individualized response

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REVIEW OF SYSTEMS

- Cardiovascular
- Integumentary
- Musculoskeletal
- Neuromuscular

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CARDIOVASCULAR SYSTEM

TESTS AND MEASURES FOR BODY STRUCTURE AND FUNCTION

- Monitor heart rate
- Monitor oxygen saturation
- Monitor blood pressure
- Chest wall shape
- Chest wall mobility
- Breathing pattern
- Tolerance to activity/rate of perceived exertion
- Endurance
- Fatigue levels

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NORMAL CARDIORESPIRATORY PARAMETERS

	Heart Rate	Respiratory Rate	Blood Pressure
Neonate	100-180	30-50	60/30-90/60
Infant	100-160	30-50	87/53-105/66
Toddler	80-110	24-40	95/53-110/69
Preschool	70-110	22-34	96/55-110/69
School age	65-110	16-24	97/57-112/71
Adolescent	60-90	12-20	112/66-126/80

Values courtesy of the Children's Hospital of Philadelphia

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IMPAIRMENTS COMMONLY ASSOCIATED WITH TREATMENT

- Deconditioning
- Cancer related fatigue
- Pulmonary complications from treatment

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DECONDITIONING/FATIGUE

- Due to treatment, prolonged admissions, abnormal blood counts

- PT Assessment:
  - General cardiopulmonary tests and measures
  - Standardized tests:
    - 6 minute walk test
    - 3 minute step test
- PT Interventions:

PULMONARY COMPLICATIONS

- Due to radiation therapy to the chest or total body irradiation; complication of bone marrow transplant
- Common diagnoses:
  - Radiation pneumonitis
  - Pulmonary fibrosis
  - Lung graft versus host disease (GVHD)
  - Bronchiolitis obliterans
- PT Assessment:
  - Chest wall measurements in various positions
  - Posture
  - Shoulder range of motion (ROM)
  - Hamstring flexibility
  - Strength assessment specifically core and proximal musculature
- PT Interventions:

LATE EFFECTS

- Heart disease
- Arrhythmia
- Hypertension
- Reduced lung function
- Dyspnea
- Pulmonary fibrosis
- Constant cough
- Pulmonary pneumonitis
- Increased risk of lung infections
- Increased risk for lung cancer

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INTEGUMENTARY SYSTEM

TESTS AND MEASURES FOR BODY STRUCTURE AND FUNCTION

- Wound characteristics
  - Location
  - Wound bed margin description
  - Drainage/exudate description
  - Wound type
  - Depth of tissue destruction
  - Tissue color
  - Infection
  - Photo documentation
- Scar characteristics:
  - Location
  - Size
  - Color
  - Moisture:
  - Elastic Turgor
  - Integrity of Tissues
  - Mobility of scar

WOUND PREVENTION

- Assess risk for skin injury
- Consider
  - Bony prominences
  - Impact of immobility
  - Sensation

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IMPAIRMENTS COMMONLY ASSOCIATED WITH TREATMENT

- Scar adhesion
- Graft versus host disease (GVHD)
- Radiation changes/burns
- Poor wound healing

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SCAR ADHESION

- Due to surgical intervention
- PT Assessment:
  - Modified Vancouver scale
- PT Interventions:

GVHD OVERVIEW

- Potential complication of allogenic transplants
- Types
  - Acute
    - Skin
    - Liver
    - Gastrointestinal tract (stomach, intestines, colon)
  - Chronic
    - Single organ to widespread
- Common medical management includes steroids

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GVHD CLASSIFICATION

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SKIN GVHD PT MANAGEMENT

- Assessment:
  - Skin injury prevention
  - ROM
  - Positioning
  - Posture
  - Mobility
  - Joint play
  - Flexibility
- Interventions:

MUSCULOSKELETAL SYSTEM

TESTS AND MEASURES FOR BODY STRUCTURE AND FUNCTION

- ROM
- Strength
- Posture
- Mobility

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RANGE OF MOTION

RANGE OF MOTION

https://www.semanticscholar.org/topic/Active-Range-of-Motion/274568

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STRENGTH

POSTURAL ASSESSMENT

- Observation
- Common postural changes
  - Head preference
  - Elevated shoulders
  - Kyphosis
  - Gravity dependent positioning
  - Foot and ankle alignment

MOBILITY

- Developmental transitions
- Functional transfers
- Gross motor skill assessment
- Gait assessment
- Stair negotiation assessment

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COMMON IMPAIRMENTS ASSOCIATED WITH TREATMENT

- Chemotherapy induced peripheral neuropathy (CIPN)
- Steroid myopathy
- Avascular necrosis (AVN)
- Orthopedic post operative complications
- Bone instability
  - Pathologic fractures
  - Bone density

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CIPN OVERVIEW

- Damage to peripheral nerves as a side effect of chemotherapy treatment
  - Vincristine, cisplatin
- Incidence

CIPN SIGNS AND SYMPTOMS

- Pain
- Burning
- Tingling
- Loss of sensation
- Balance problems
- Difficulty walking/climbing stairs
- Increased sensitivity to temperature/touch/pressure
- Muscle atrophy
- Muscle weakness
- Diminished or absent reflexes
- Audible foot slap

CIPN PT ASSESSMENT

- Ankle dorsiflexion ROM
- Great toe extension and tibialis anterior muscle strength
- Popliteal angle
- Achilles reflex
- Sensation/vibration
- Foot posture/alignment
- Balance
- Gait
- Standardized tests:
  - Ped-mTNS
  - Pediatric balance scale

CIPN PT INTERVENTIONS

CIPN PROGNOSIS

STEROID MYOPATHY OVERVIEW

- Insidious disease process that causes weakness to the proximal muscles of the upper and lower extremities
- Signs and symptoms:
  - Symmetric, proximal muscle weakness
  - Malaise
  - Fatigue
  - Absence of sensory complaints

STEROID MYOPATHY PT MANAGEMENT

- Assessment:
  - General musculoskeletal test and measure with focus on proximal musculature
- Interventions:

AVN

- Death of bone tissue due to lack of blood supply
- Side effect of steroid treatment
- PT Assessment:
  - General musculoskeletal tests and measures
  - Pain
  - Mobility
- PT Interventions:

ORTHOPEDIC POST OPERATIVE COMPLICATIONS OVERVIEW

- Due to surgery for localized treatment
- Common complications:
  - Pain
  - ROM deficits
  - Weakness
  - Immobility
  - Altered sensation
  - Leg length discrepancies
  - Nerve damage
  - Postural abnormalities
  - Altered gait mechanics
  - Wound dehiscence/infection
  - Hardware failure
  - Repeat surgeries

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ORTHOPEDIC POST OPERATIVE COMPLICATIONS PT MANAGEMENT

-
- Assessment
  - General musculoskeletal tests and measures

INTERVENTIONS

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LATE EFFECTS

- Stunted growth
- Bone pain
- Joint stiffness
- Decreased bone density
- Gait alterations

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NEUROMUSCULAR SYSTEM

TESTS AND MEASURES FOR BODY STRUCTURE AND FUNCTION

- Muscle tone
- Reflexes
- Balance
- Coordination
- Proprioception
- Sensation
- Level of arousal
- Cognition
- Cranial nerve testing
- Vision/hearing

COMMON IMPAIRMENTS ASSOCIATED WITH TREATMENT

- Posterior fossa syndrome
- Ataxia
- Spasticity
- Hemiplegia

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POSTERIOR FOSSA SYNDROME OVERVIEW

- A postoperative syndrome involving a variety of clinical characteristics
  - Neurological
  - Neuropsychological
  - Neurolinguistic
- Incidence: Reports vary from 2-50%
- Onset: Varies from 24-107 hours post operatively
- Duration: Weeks to months

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POSTERIOR FOSSA SYNDROME SIGNS AND SYMPTOMS

Motor	Cognitive	Affect/Behavior	Speech/Language
• Ataxia • Dysmetria • Dysphagia • Dysarthria • Hypotonia • Hemiparesis • Nystagmus • Oculomotor problems • Urinary retention/incontinence	• Attention • Memory • Executive functioning • Visuospatial skills • Processing speed • Verbal comprehension • Reading/writing difficulties	• Depression • Irritability • Lability • Apathy • Anxiety • Forced crying/laughter • Transient eye closure • Impulsivity	• Cerebellar mutism • Naming problems • Verbal fluency • Dysarthria • Slowed speech • Decreased verbal output • Short phrases • Distorted vowels • Prolonged phonemes • Mono-pitch/loudness • Hypernasality • Vocal tremor

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POSTERIOR FOSSA SYNDROME PT MANAGEMENT

- Assessment:
  - General neuromuscular tests and measures
  - Speech and language screening
  - Cognitive screening
  - Affect and behavior screening
- Interventions:

POSTERIOR FOSSA SYNDROME PROGNOSIS

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ATAXIA OVERVIEW

- Lack of voluntary coordination of muscle movements

ATAXIA PT MANAGEMENT

- Assessment
  - Ataxia rating scale
  - Mobility
- Interventions

SPASTICITY

- Due to damage of the nerves in the central nervous system.
- Altered muscle movement patterns with hypertonia and increased tendon reflex activity
- Managed with oral medications, local injections or intrathecal baclofen
- PT assessment:
  - Modified Ashworth Score
  - ROM measurements
  - Mobility and ADL's
- PT interventions:

LATE EFFECTS

- Neurocognitive impairments
  - Lower IQ scores
  - Poor attention/memory
  - Poor hand eye coordination
  - Behavioral problems
- Developmental delay
- Pituitary issues
- Seizures
- Headaches

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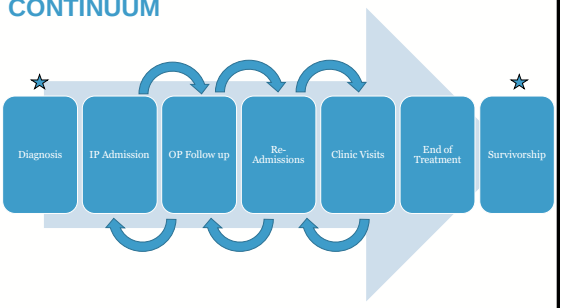
EVALUATION

Diagnosis, Prognosis, Plan of Care

CANCER REHABILITATION ACROSS THE CONTINUUM



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DIAGNOSIS AND PROGNOSIS

- PT Diagnosis
  - Based on impairments
- Prognosis depends on:
  - Type of cancer
  - Grade/stage of cancer
  - Type of treatment
  - Social and physical supports
  - Psychological
  - Barriers to accessing care

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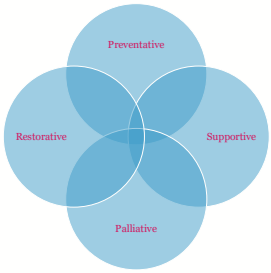
FOCUS OF PT GOALS AND INTERVENTIONS



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PT PLAN OF CARE ACROSS SETTINGS

	Acute Care	Rehab	Outpatient	Early Intervention	School Based Therapy
Who	• Change in functional status • Change in medical status • New diagnosis • Prolonged admission	• Acute change in functional status requiring intensive PT with daily progress	Require ongoing skilled PT treatment	EI: 0-3 years old IU: 3-5 years old	PT impairments which limit access to school environment or activities
Where	Bedside	Rehab gym	Outpatient gym	Home or daycare	School
Frequency	Variable: 1-7x/week	Daily	1-3x/week	Variable: 1-7x/week	1-3x/week
Goals	• Safety for home • Return to functional baseline • Minimize skill regression • Prevention of co-morbidities	• Safety for home • Return to functional baseline • Compensatory strategies • DME • Family training	• School re-entry • Return to recreational activities • Compensatory strategies • Quality of movement • DME/bracing	• Developmental skill acquisition • Family education	• Normalizing peer interactions • Optimizing navigation of school environment • Optimizing activity and participation limitations

SURVIVORSHIP

SURVIVORSHIP

- Maximizing outcomes while minimizing long term side effects and the impact on growth
- Promoting health and wellness
- Improving quality of life
- Improving access to ongoing medical care, support, and surveillance for late effects
- Support for patients and families
- Screening of educational and vocational progress

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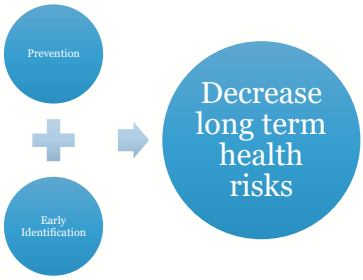
SURVIVORSHIP



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REHABILITATION NEEDS OF SURVIVORS

- Pain
- Fatigue
- Impaired mobility
- Decreased range of motion
- Decreased strength
- Impaired activities of daily living
- Cognitive impairments
- Neuropathy/nerve disorders
- Low back pain
- General musculoskeletal symptoms

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CASE STUDIES

Pediatric Cancers

THANK YOU

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QUESTIONS

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DEVELOPMENTAL APPENDIX

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INFANT POSTURE

- 1 month: physiological flexion, fully rounded back, flexed neck

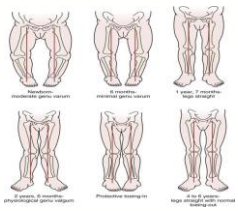
INFANT POSTURE

- 3 months: beginning of symmetry, antigravity flexor control emerges, midline orientation of head emerges

INFANT POSTURE

- 4 months: strong symmetry, bilateral control of extensor and flexor muscles, emergence of controlled purposeful movement

LOWER EXTREMITY POSTURAL DEVELOPMENT



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PRIMITIVE INFANT REFLEXES

Primitive Reflex	Purpose of Reflex	Appears	Should Integrate By:	Signs of Retention
Moro Reflex	Primitive Fight or Flight Reaction	Birth	2 to 4 Months	Hyper Sensitivity, Hyper Reactivity, Poor Impulse Control, Sensory Overload, Social & Emotional Immaturity
Rooting Reflex	Automatic Response to Turn Towards Food	Birth	3 to 4 Months	Fussing Eating, Thumb Sucking, Dribbling, Speech and Articulation Problems
Palmer Reflex	Automatic Flexing of Fingers to Grab	Birth	5 to 6 Months	Difficulty with Fine Motor Skills, Poor Manual Dexterity, Messy Handwriting
ATNR	To Assist Baby Through Birth Canal and Develop Cross Pattern Movements	Birth	6 Months	Poor Eye-Hand Coordination, Difficulty with Handwriting, Trouble Crossing Vertical Mid-line, Poor Visual Tracking for Reading and Writing
Spinal Gallant Reflex	Assist Baby with Birth Process	Birth	3 to 9 Months	Unilateral or Bilateral Postural Issues, Fidgeting, Bedwetting, Poor Concentration, Poor Short Term Memory
TLR	Basis for Head Management and Postural Stability Using Major Muscle Groups	In Utero	3 1/2 Years	Poor Muscle Tone, Tendency to Walk on Toes, Poor Balance, Motion Sickness, Spatial Orientation Issues
Landau Reflex	Assist with Posture Development	4 to 5 Months	1 Year	Poor Motor Development
STNR	Preparation for Crawling	6 to 9 Months	9 to 11 Months	Tendency to Slump While Sitting, Poor Muscle Tone, Poor Eye-Hand Coordination, Inability to Sit Still and Concentrate

Retained primitive reflexes as a sign of brain imbalance. Brain Balance Centers website https://blog.brainbalancecenters.com/2014/09/retained-primitive-reflexes-sign-brain-imbalance. Access November 1, 2018.

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PROTECTIVE EXTENSION REACTIONS IN SITTING

Reflex	Onset	Integration	Stimulus	Response
Forward	6-7 months	Persists	Displace center of gravity outside base of support forward	Lower extremities and UE's extend and abduct to protect and support body
Lateral	7 months	Persists	Same as above except displacing laterally	Same as above
Backwards	9-10 months	Persists	Same as above except displacing backwards	Same as above

EQUILIBRIUM REACTIONS

Reflex	Onset	Integration	Stimulus	Response
Prone	6 months	Persists	Tilt supporting surface to displace center of gravity	Abduction and extension or extremities, with curvature of trunk
Sitting	7-8 months	Persists	Same as above	Trunk extension or flexion to A/P displacement, abduction and extension of extremities to lateral displacement with trunk rotation
Quadruped	9-12 months	Persists	Same as above	Similar to prone
Standing	12-21 months	Persists	Same as above	Ankle dorsiflexion/plantarflexion, hip flexion or extension, trunk flexion or extension

STAGES OF LOCOMOTOR DEVELOPMENT

- Early stepping
- Rolling
- Crawling
- Creeping
- Cruising
- Erect ambulation
- Running
- Galloping
- Hopping
- Skipping

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KEY GROSS MOTOR SKILLS

3.5 months	Rolls prone > supine
6.5 months	Sits independently Rolls supine > prone
9.5 months	Creeps, cruises
12 months.	Walks 2-3 steps Stands alone well
13.5 months	Creeps up stairs
22 months	Runs Walks upstairs holding rail
28 months	Jumps with both feet
4 years old	Skipping, galloping

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DEVELOPMENT OF GAIT

- 9-15 months:
  - Wide base of support
  - Hips abducted, flexed and externally rotated
  - Tibia in mild internal torsion and varus
  - Elevated center of mass
  - Increased hip and knee flexion
  - Full foot initial contact
  - Short stride, increased cadence

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DEVELOPMENT OF GAIT

- 18-24 months:
  - Limb is straight at 18 months of age
  - Decrease in base of support
  - Prolonged stance phase
  - Increased cadence
  - Center of mass descends to proximal end of legs
  - Heel strike develops

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DEVELOPMENT OF GAIT

- 3 to 3.5 years:
  - Mature patterns
  - Tibiofemoral angle-valgus alignment
  - Decreasing femoral antetorsion of the hip
  - Center of mass closer to extremities
  - Consistent heel strike with knee flexion

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DEVELOPMENT OF GAIT

- 6 to 7 years:
  - Fully mature gait pattern
  - Tibiofemoral angle returns to neutral
  - Femoral antetorsion is resolved
  - Heel position is neutral
  - Center of mass at level of third lumbar vertebrae

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DEVELOPMENT OF RUNNING

- 18 months – early running, modified walking, limited range of motion, short stride length
- 2-3 years – smoother stride and run
- 4-5 years – improvement in power and form
- 5-6 years – advance to level of adult pattern
- 6 years – refined adult running pattern

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DEVELOPMENT OF STAIR NEGOTIATION

- 18-24 months: Places two feet on each with handrail
- 2-3 years of age: 2 feet on each step without support; 1 foot on each step with handrail
- 3-4 years of age: walks up and down steps with 1 foot on each step without support

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DEVELOPMENT OF JUMPING

- 24 months – jump down from 12 inches
- 28 months – jump off floor both feet
- 31 months – jump down 18 inches 1 foot leading
- 32-33 months – jump down 12 inches both feet
- 37 months – jump down 14-18 inches both feet
- 37 months – jump forward 4-14 inches
- 38 months – hop on 2 feet 1-3 times
- 43 months – hop on 1 foot 1-3 times

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PEDIATRIC STANDARDIZED OUTCOME MEASURES

Test	Age	Domains Tested
Pediatric Balance Scale	2.5 to 7 years *	Balance
Balance Error Scoring System (BESS)	5 to 14 years	Balance
Wee Functional Independence Measure (Wee FIM)	6 months to 7 years *	Self care Mobility Cognition
Pediatric modified total neuropathy scale (Ped-mTNS)	5 to 18 years	Peripheral Neuropathy
6 Minute Walk Test	3 to 18 years	Cardiopulmonary
PedsQL	2 to 18 years	Quality of life

* Can be used above age range if child is expected to be delayed in these areas. Ceiling effect present at upper end of age range

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PEDIATRIC STANDARDIZED OUTCOME MEASURES

Test	Age	Domains Tested
Alberta Infant Motor Scale (AIMS)	0 to 18 months	Gross motor skills
Peabody Developmental Motor Scales 2 (PDMS-2)	Newborn to 6 years 11 months	Gross motor skills Fine motor skills Visual motor skills
Bayley Scales of Infant Development	1 month to 3.5 years	Gross motor skills Fine motor skills Cognition Language
Bruininks –Oseretsky Test of Motor Proficiency (BOT-2)	4 to 21 years	Fine motor skills Coordination Balance Strength

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