BONE METASTASIS

Bone Mets

- Bone is 3rd most common metastatic site
- >75% of bone mets are from breast, prostate, or lung
- Lung is 3rd most common origin
- If primary unknown, most likely are lung or kidney
- First manifestation of cancer in 12 to 20%
- Pain is the most common presenting sx
- Lung = Lytic more common than blastic
  (***L***ung and ***B***reast can be ***L***ytic or ***B***lastic)

Bone Mets

- Thyroid: 4-13% bone met incidence
- Renal cell: 25-50% bone met incidence
- Both usually lytic, but renal can be more expansile and destructive
- Both high risk for pathologic fx

Bone Mets

- Most common bone sites = Spine, Femur, Humerus, Ribs, Pelvis, Cranium, Sternum
  - "FISH" Bones (femur, ilium, spine, humeri)
- 50% of hand bone mets are due to lung CA
- AXIAL = always "**A**xial e**X**cept **I**n **A** Lung"
- "Lung lesions go Long"
- Lung neoplastic cells gain arterial access
- Usual venous pathways go to liver and lung

Spine Mets

- Vertebral column is most common site
- Incidence greatest in L>T>C spine
- T-spine accounts for most symptomatic cases (70% thoracic – predilection for T4 and T12)
- Bonescans are sensitive but not specific
- X-rays are good initial screen
- CT or MRI for suspicious sx's if x-rays normal

Prognosis

- Avg 6 months after bone met in lung CA
  (Avg 29 months after bone met in prostate CA)
- Stage IIIB NSCLC has 37% 1 yr and 7% 5 yr survival
- 25% of all long bone mets fracture, but proximal femur has 40-60% incidence
- Lytic more likely to fx than blastic

Treatment Options

- XRT
- Surgery
- Bisphosphonates
- Opioids
- Calcitonin/Vitamin D/Calcium
- Steroids for inflammation/pain
- Chemotherapy directed at primary cancer
- Limit weight-bearing, assistive devices
- Spinal orthoses

Radiation Therapy

- XRT: *depends on cancer type*
  - 95% stay ambulatory if walking pre-XRT
  - 60% improve if limited walking pre-XRT
  - <40% recover b/b function if lost before XRT
- Irradiation might increase risk of fx
  - Temporary softening and less reossification
- XRT+surgery vs XRT: controversial
- Peri-op mortality 8%. Peri-op infxn rate 4%

Surgical indications

- Intractable pain
- Impending pathologic fracture
- Established fracture
- Life expectancy >6 weeks (controversial)

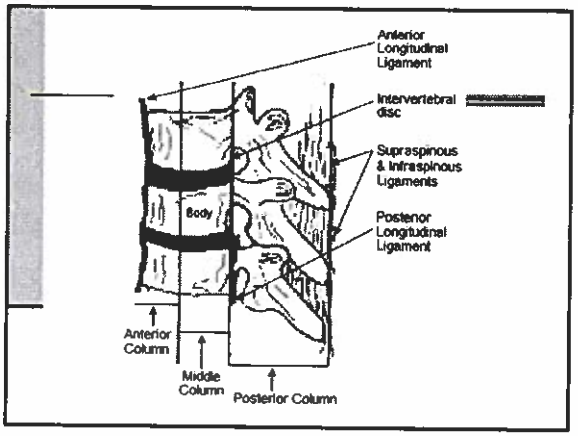
Pathologic fracture risk factors

Femur:

>1.3 cm femoral neck cortical destruction
>2.5 cm elsewhere in femur
>50% total diameter involvement
>30-50% cortex involvement

Spine:

Denis (*Spine* 1983) 3 column spine model:
Unstable if 2 or more columns involved or if the middle column is severely distorted



Surgical criteria

Mirel's criteria for long bones:

- 1) Pain: mild, moderate, severe
- 2) Location: UE,LE, intertrochanteric
- 3) Size: <1/3 cortex, 1/3-2/3, >2/3 cortex
- 4) Type: blastic, mixed, lytic

Assign 1-3 points for each category.

>9 points = surgery

Spine surgery approach

- For diffuse disease, posterior approach used for decompression and stabilization via fixation of 2 levels above and 2 levels below
- For 1-2 levels, anterior approach better
- Vertebroplasty for 1-2 level vertebrae can be considered but can be risky with brittle bone
- Treatment plan must always involve intense counseling with patient, family, and team

CANCER REHABILITATION

Has become #1 cause of death in the United States

Deficits: **#1)Gait** 2) ADLs 3) vocation 4)Depression (Braddom)
#1) weakness 2) ADLs 3) pain 4) ambulation (Lehman from C)

Stages of disease
Preventive: goal to achieve maximal function for patients who are cured or in remission
Supportive: providing adaptive self-care equipment to offset expected decline, ROM
Palliative: improve or maintain comfort and function during terminal stages
Marciniak: rehab helps, especially with brain cancer

NUTRITION

Many cancer patients place ability to eat at top of determining physical well-being
40-80% malnourished: impaired wound healing, immunocomprimised, endocrine dysfunction, fluid imbalance
Caloric intake: 115-130% of resting energy expenditure
Protein 1.5-2.5 g/kg/day
Learned food aversion: meats, veggies, caffeine
Encourage to eat very little before therapy
Appetite stimulants: megestrol
Treat emesis with serotonin antagonist: ie Zofran (odansetron hydrochloride) = 5HT blocker

RADIATION

Nutritional imparments (includes surgery)
Head and neck: alters taste and saliva production, impaired mastication, swallowing , smell
Esophagus: gastric statis, diarrhea, steatorrhea
Pancreatomy: DM, impaired digestion
Bowel resection: malabsorption, Vit B12, D, A deficiencies
Gastrectomy: impaired digesion, malabsorption, megaloblastic anemia, hypoglycemis
Stomach and intestines: nausea, vomiting, cramps, diarrhea
Chronic problems: obstruction, intestinal perforation, GI bleed, malabsorption, enteral fistuals
Diet: lactose-free, low residue oral diets, small frequent meals, increase fluids
Parenteral nutrition recommneted if lost >20% of body weight

Transient myelopathy/Lhermitte's syndrome: Radiation induced spinal cord damage
head and neck, lymphoma RTX
occurs after latent period 1- 30 months
peak 4-6 months
resolves 1-9 months after onset
imaging normal
+Lhermittes sign
Not a risk factor of delayed myelopathy

Delayed radiation myelopathy
Irreversible with incidence of 1-12%
Onset 9-18 months after completing treatment
Latent periord decreases with increased radiation, shortened in children
LE paresthesias → sphinter dysfunction → weakness
Partial Brown-Sequard syndrome can develop
Progressive deficits
20% get central pain syndrome: TCA. Steroid, anticonvulsants

Post radiation plexopathy
Occurs with breast, lung, mediastinal tumors and lymphoma
Latency 1 month – 15 years
Resents with paresthesias and pain
Signs: sensory loss, depressed reflexes, weakness
Distinguishing between plexopathy and tumor invasion
Tumor invasion 10x more common
Associated with Horner's syndrome, lower trunk involvement, pain
Radiation: upper trunk involvement more common, lymphedema
myokymic discharges, abnormal sensory conduction

Lumbosacral plexopathy
colorectal & gyn tumors
present with bilateral>>>unilateral pain, paresthesias prior to weakness

radiation may damage nerve itself, or surrounding structures: weakness, parasthesias, decreased ROM, atrophy

THROMBOCYTOPENIA
Platelets **<10,000/ml** preclude exercise therapy
Increased risk of ICH
Some centers allow aerobic but not resistive activities in patients with platelets 10,000-20,000/ml

PAIN
25% die with unrelieved pain (WHO)
Unrelieved pain is risk factor for suicide
Etiologies
#1 tumor invasion of bone
#2 compressionr/infiltration of peripheral nerves by tumor
mucositis 2/2 RTX and CTX
peripheral neuropathies: taxanes, vinca alkaloids, platinum
treatment algorithm: **WHO's three step ladder**
start with non-opiods +/- adjuvant: **ceiling effect**
then add opioid for mild-mod pain: **no ceiling effect**
then add opiod for mod-severe pain
Addiction: behavioral syndrome of compulsive, harmful use not requiring the existence of physical dependence or tolerance, not likely in cancer patients without h/o substance abuse

Peripheral neuropathy can occur with tumors of lung, multiple myloma, breast, colon

CHEMOTHERAPTHY
Methotrexate: inhibits folic acid metabolism (synthesis of DNA)
SE macrocytic anemia, leukopenia, ulcerative stomatitis
Vit B_1 deficiency: occurs with severe and recurrent vomiting
Results in beriberi (muscle weakness, tachycardia, heart failure)
thiamine deficiency: parasthesias, neuropathy, heart failure
occurs with **5-fluorouracil and 6-mercatopurine** (prevent nucleic acid synthesis)
Vit K deficiency: bleeding, ecchymosis
Occurs with long-term antibiotic treatment
Cisplatin: distal symmetrical sensory neuropathy, autonomic neuropathies with fluctuation BP, HR
Vincristine: severe PPN, hearing loss, autonomic neuropathies with fluctuation BP, HR
Cytarabine: PPN

TABLE 9-10. Chemotherapeutic Agents and Side Effects

Cytoxan	Hemorrhagic cystitis, bladder fibrosis, bladder carcinoma, cardiac necrosis (massive doses), stomatitis
Nitrogen Mustard	Skin necrosis if extravasated, dermatitis, neurologic toxicity (rare)
Nitrosoureas	Stomatitis, lung fibrosis, ataxia, organic brain syndrome, optic neuritis
Platinum complexes	Nephrotoxicity, ototoxicity, peripheral neuropathy, loss of taste, seizures
Azacitidine	Hepatic dysfunction, rhabdomyolysis, lethargy, weakness, confusion, fever, skin rashes, stomatitis, phlebitis, hypotension
Cytarabine	Arachnoiditis with intrathecal administration, stomatitis, esophagitis, hepatic dysfunction (mild, reversible), thrombophlebitis
Fluorouracil	Diarrhea, stomatitis, esophagitis, intestinal bleeding, dermatitis, photosensitivity, loss of nails or dark band on nails, "black hairy tongue," lacrimation, lacrimal duct stenosis, cerebellar ataxia, myocardial ischemia
Mercaptopurine	Cholestasis, stomatitis, diarrhea, dermatitis, fever, hematuria, Budd-Chiari-like syndrome
Methotrexate	Stomatitis, diarrhea (intestinal hemorrhagic, ulceration, perforation), renal tubular necrosis, liver cirrhosis, osteoporosis (in children), dermatitis, furunculosis, fever, headache, pneumonitis Intrathecal: arachnoiditis with radicular syndrome, myelitis, seizures Previously irradiated areas: skin erythema, pulmonary fibrosis, transverse myelitis, cerebritis
Thioguanine	Cholestasis
Actinomycin D	Stomatitis, cheilitis, glossitis, proctitis, diarrhea, skin erythema, desquamation, hyperpigmentation, necrosis with SQ injection
Bleomycin	Shaking chills, fever, anaphylaxis-like reaction with hypotension, fever, delirium, bronchospasm in lymphoma patients, severe pneumonitis, pulmonary fibrosis, skin hyperpigmentation, hardening/loss of fingernails, erythroderma, desquamation
Doxorubicin (Adriamycin), Daunorubicin, Adriamycin	Cardiomyopathy, stomatitis Extravasation: severe ulceration and necrosis Erythema, desquamation in previously irradiated skin areas, diarrhea
Mitomycin C	Necrosis with SQ injection, stomatitis, rash, pulmonary fibrosis, hepatic and renal dysfunction
Vinblastine	Local vesication if injected SQ, stomatitis, glossitis, neurologic toxicities similar to vincristine
Vincristine	Peripheral neuropathy with severe paresthesias, paralytic ileus, abdominal pain, local vesicant if injected SQ
Vindesine	Neurotoxicity as per vincristine, but less severe
VP-16-213 (etoposide, VP-16)	Orthostatic hypotension with rapid infusion
L-Asparaginase	Allergic reactions, hepatitis (< 50%), pancreatitis (5%), coagulation deficits, CNS depression, glucose intolerance
Dacarbazine (DTIC)	Local irritant if injected SQ, flulike syndrome, hepatotoxicity, diarrhea, cerebral dysfunction
Hexamethylmelamine (HMM)	Rash, neurotoxicity
Hydroxyurea	Stomatitis, rash, headaches, increased blood urea nitrogen
Mitotane	Diarrhea, depression, lethargy, dermatitis, permanent cerebral dysfunction (rare)
Procarbazine	Lethargy, depression, muscle cramps, arthralgia, sensitization of tissue to radiation, peripheral neuropathy, vertigo, headache, seizures, dermatitis (hyperpigmentation), stomatitis, dysphagia, diarrhea
Streptozocin	Nephrotoxicity, renal tubular acidosis, renal failure, hepatotoxicity, diarrhea
Adrenocorticosteroids	Peptic ulcer disease, Na retention, hypertension, K wasting, glucose intolerance, weight gain, proximal myopathy, Psychologic effects: euphoria, depression, psychosis Osteoporosis, avascular hip necrosis, skin fragility, susceptibility to infection
Androgens	Virilization, fluid retention, hepatotoxicity
Estrogens	Fluid retention, feminization, uterine bleeding, hypercalcemic flare (breast cancer)
Progestins	Mild fluid retention
Taxol	Hypersensitivity reactions, peripheral polyneuropathy, myalgia, arthralgias, bradycardia
Suramin	Peripheral polyneuropathy, coagulopathy, adrenal insufficiency, renal toxicity

(Cascioto 1988)

BRAIN TUMORS
Slow growing often do not cause cognitive deficits
Most patients have significant return of function after surgical resection
Improvements in cognition seen with methylphenidate 10 bid
Radiation: subacute affects can occur 1-4 months after completed due to reversible demylination
Delayed effects can occur after 6-12 months
Focal necrosis, atrophy, calcification, necrotizing leukoencephalopathy, aneurysms, secondary CA
Chemotherapy: 18% with deficits
3 weeks after discontinued
Impaired visual perception, verbal memory, judgement
More deficits with multimodal therapy than single

Adult brain tumors
Headache is most common presenting symptom
Weakness is most common sign
Seizures frequently are the first presenting sign
60%-90% of primary CNS tumors are high grade **astrocytomas**
most common tumors of brain are metastatic
carcinomas from **breast or lung**>GI, urinary tract, melanoma
pounding headache = LBS KG
lung>breast>skin>kidney>GI
cerebrum (frontal lobe most common) >cerebellum>brainstem
GBM or high grade astrocytomas: most less than 2 years survival

Pedicatric Brain tumors
Second most common malignancy of childhood (after leukemia)
Low grade astrocytomas are most common primary brain tumors in children
Medulloblastomas 20% of intracranial in children, located near cerebellar vermis
Tend to be infratentorial (adults tend to be supratentorial): nausea and vomiting

SPINAL CORD LESIONS
Majority metastatic
95% extradural
Most arise in vertebral body and compress anterior cord
70% of diagnoses mets occur in **thoracic spine** because has smaller canal to cord diameter
Presents with pain, worse **recumbent** position
Rapid evolution of paraparesis over several hours usually signifies arterial compromise by tumor invasion or pressure with guarded prognosis for recovery
Stability is of concern if tumor involves 2-3 vertebrae
Sternal-occipital-mandibular immobilization is tolerated better than Halo fixation, better stabilization than Philadelphia collar

BREAST CA
18% of cancer deaths in women
#1 cause of death for 40-55 year old women
Radical mastectomy: resection of pectoralis major and minor, axillary lymph nodes
Shoulder dysfunction, pain, lymphedema, emotional trauma
Modified radical mastectomies: spare the pectoralis major, more common
Transverse Rectous Abdominis Muscle (TRAM) flap: weakened abdominals
First month s/p modified radical mastectomy
Tight chest wall>difficulty lifting,>limited mobility>arm weakness>lymphedema>numbness
Early PT improves post-op shoulder motion
Shoulder abduction and flexion 45-90 allowed postop
Hand pumps, elbow AROM, shoulder PROM with progression to FROM

Lymphedema = 25-40%

Onset after 2 years could mean tumor reoccurrance

Progresses if untreated and increases risk of cellulites, further lymphatic damage and extremity enlargement, and vicious cycle

Elevation, manual lymphatic drainage, compressive bandaging and garments, pneumatic pumps

Temporary prosthesis postop

Permanent prosthesis fitted at 3-8 weeks, after edema resolved and chest wall healed

Grading

Grade I Pitting edema reversed by elevation

Grade 2: Nonpitting, brawny, hardened skin 2/2 fibrotic tissue due to chronic excess protein in the interstitial spaces and deposition of adipose tissue. Unresponsive to elevation.

Grade 3 lymphostatic elephantiasis, cartilage-like

BONE TUMORS

Osteosarcomas of knee and proximal humerus are most common sarcomas in adults and children

80% five year survival

Amputation is preferred for high-grade malignancies of the **distal lower extremity**

Provides good function and less morbidity than salvage or reconstruction

CTX induced fatigue, anemia, nausea, cardiovascular toxic effects can diminish functional capacity

Anorexia, muscle atrophy and fluid shifts can delay definitive prosthesis

Delay in would healing over irradiated ports

Skin less tolerant to prosthesis wear

Metastatic bone lesions

40x more common than primary lesions

breast: 50-85% of all bone mets

prostate: most common for mets in men 60%

hematogenous spread: **Batson's plexus**

lung, renal, bladder, thyroid, bowel

myelopma

painful, progressive, **worse at night**

bone scans often have false negative results in lung, melanoma and multiple myeloma

In Patients with Metastatic Bone Disease

- 75% have breast, lung or prostate cancer
  25% have renal, thyroid, or other cancer
  60% of all bone metastasis in males are secondary to prostate cancer, and approximately > 90% of patients with advanced prostate CA will develop bone metastases
  50% to 85% of bone metastasis in females are secondary to breast cancer
- More than 50% of all patients with breast, lung, or prostate cancer will eventually develop bone metastasis. Skeletal metastasis arise through hematogenous spread. Bone is the third most common site for metastasis.

Involvement of the Upper Extremity

More than 90% of upper extremity metastasis involve the humerus.

- In the upper extremity the majority of symptomatic lesions are from:
  1. Breast Ca
  2. Multiple Myeloma
  3. Renal Ca

Involvement of the Lower Extremity

Most metastasis of the lower extremity involve the hip and femur.

- In the lower extremity the majority of symptomatic lesions are from:

HIP	FEMUR
Prostate CA	Breast CA
Breast CA	Renal CA
Lung CA	Multiple Myeloma
Lymphoma	Prostate CA

Pathologic fractures

10-30% of patients with mets

Fx most common in long bones: femur, humerus

Increased fx risk if destruction >50% of cortical diameter, >2.5 cm in diameter, or involves >50% of medullary cross-sectional area or cortex

bone susceptible to torsion and rotation because forces no longer uniformly transmitted

CT with coronal views

Surgical fixation with removal of tumor through curettage, uses of methyl methacrylate, IM rods, modular prosthesis

Radiation treatments create transient softening of bone in increase fx risk for 6-8 weeks

May consider reduced weight bearing

Surgical Intervention Is Indicated When:

	Size of Lesion	Amount Cortex Involved
Upper Extremity	> 3 cm	> 50%
Lower Extremity	> 2.5 cm	> 30% to 50%
(Figure 9-9)		femoral neck > 1.3 cm in axial length

- Surgical intervention if greater than 50% to 60% of medullary cross-sectional diameter is involved
- Surgical intervention if involvement of a lesion of cortex equal to or greater than the cross sectional diameter of the bone
- This determination is enhanced by CT sections

(Gerber, Vargo 1998)

- **Lytic Lesions** are generally considered to be more prone to fracture than blastic lesions
- **Lytic Lesions** typically occur in tumors of the:
  - Breast
  - Lung
  - Kidney
  - Thyroid
  - Gastrointestinal tumors
  - Neuroblastoma
  - Lymphoma
  - Melanoma

(Blastic Lesion typically occur in Prostate Cancer)

Blastic = BPH (prostate)

3 **BBB'S** Love to Lick Pollen

Bladder, **B**ronchus, **B**reast, Skin, Lung, Lymphoma, **P**rostate

Lytic = **BLT** with Ketsup & Mustard

Breast, Lung, **T**hyroid, **K**idney (renal cell), Melanoma

INVOLVEMENT OF THE AXIAL SKELETON

- Requires evaluation of the extent of metastatic involvement of the vertebral column. An MRI will clearly delineate epidural vertebral involvement even if radiographs are normal.
- Denis (1984) described stability of thoracic and lumbar injuries by utilizing the three-column model described as : (Figure 9-10)

Anterior Column	Middle Column	Posterior Column
Anterior longitudinal ligament	Posterior half of vertebral body	Spinous process
Anterior half of vertebral body	Posterior annulus/ posterior disc	Laminae
Anterior annulus fibrosis		Facets
	Posterior longitudinal	
Anterior disc	ligament	Pedicles
		Posterior ligamentous
		structures:
		Ligamentum flavum
		Intraspinous ligaments
		Supraspinous ligaments

- The spine is considered stable when only one column is involved except if it is the middle column.
- The spine is considered unstable when two or more columns are involved or the middle column is severely involved.
- The spine is also considered unstable if greater than 20 degrees of angulation is present.
- These basic principles can be applied in evaluating metastatic bony involvement of the spine. (Denis 1984)

HEAD AND NECK

5% of all malignancies: larynx most common

Radical neck disection

spinal accessory nerve usually sacrificed: loss of trapezius
scapula moves laterally and deepens the axilla

limited shoulder abduction = shoulder pain

REHAB: **strengthen levator scapulae, rhomboids, serratus anterior** to stabilize scapula, diminish pain
avoid strenthening deltoid, supraspinatus and infraspinatus→ increases pain, overworks disadvantaged muscles
avoid contracture of unopposed pectoralis muscle

unilateral disruption of SCM, platysma, omohyoid can lead to asymmetrical neck motion
often need to support nech and head when changing from supine to sitting

bilateral, cannot flex neck
ROM initiated once sutures removed
advanced to active resistive strengthening by post op week 4-6
scar massage daily

PEDIATRIC

Most common childhood CA is **leukemia: ALL**
Increased risk of falling behind a grade level

Brain irradiation is associated with cognitive decline especially if less than 7 years old

Usually have abnormal growth patterns after treatment

17% incidence of developing second malignancy by 20 years

MISCELLANEOUS

Pancoast's syndrome

carcinomas in superior pulmonary sulcus

pain in c8-T2 distribution

Horner's syndrome

pain in shoulder and vertebral border of scapula

RX: surgery and radiation

Van Nes procedure: ankle becomes knee

Tikhoff-Lindberg procedure: en bloc humeral interscapulothoracic resection

Myopathy: Paraneoplastic Polymyositis and Dermatomyositis
Associated with malignancies of breast and lung
Carcinomatous Myopathy – syndrome in metastatic disease consistent with muscle necrosis, presents with proximal muscle weakness
Carcinomatous neuropathy – affects peripheral nerves and muscle. Distal motor and sensory loss, proximal muscle weakness, decreased reflexes and sensation. Occurs with lung cancer. Type II muscle atrophy.
Steroid myopathy: atrophy of type II muscle fibers of proximal musculature
Isometrics used to improve muscle strength

II. Multiple Myeloma

- Represents **10% to 25% of patients with pathologic fractures**
- Characterized by presence of **cells resembling plasma** cells originating in the bone marrow. This **abnormal protein leads to termination of cells**
- Occurs most commonly in patients **50 to 70 year old Males > female**
- Usually progresses with gradual development of pain
- Frequently involves the lumbar spine, pelvis/sacrum, chest, skull, and ribs
- Often, there **may be no early findings** and pathologic fracture may be the presenting manifestation of the disease
- Course of disease is insidious and eventually leads to extensive marrow replacement, anemia, thrombocytopenia, and hemorrhages

Complications:
- **Renal failure** occurs as a result of tubular blockage by protein cast deposition
- Bone involvement on roentgenograph reveals diffuse osteoporosis and multiple lytic lesions
- Early films are often negative
- Bone scans may be normal. However, a skeletal survey may reveal diffuse "punched out" lytic lesions with black sclerotic borders
- Amyloid deposits may also infiltrate peripheral nerves causing a peripheral neuropathy.

Treatment:
- Radiotherapy
- Chemotherapy
- Intramedullary fixation – may be difficult or impossible because of the remaining abnormal bone
- Rehabilitation concerns are similar to those patients with metastatic involvement or other primary malignancies. A high index of suspicion is necessary to identify patients at risk for pathologic fractures.

CARDIAC REHAB

Benefits: 1) increase functional capacity 2) reduce morbidity and mortality
Outcomes: improved exercise tolerance, cardiac symptoms, blood lipid levels, psychosocial well being, reduced mortality
Patient's referred: MI, CABG, cardiac transplant, post-valve replacement, CHF, arrythmias

RISK FACTORS

(*Braddom*)
Irreversible: male, fam hx, h/o CAD, PVD, CVA
Reversible: smoking, HTN, Low HDL (<35), High lipoprotein A, abdominal obesity, hypertriglyceridemia (>250), hyperinsulinemia, DM, sedentary lifestyle

Modifiable Risk Factors: (*Framing ham Study* 1984)
HTN, cigarette, hypercholesterolemia, low HDL (<35), sedentary, DM, stress, obesity
Non-modifiable Risk Factors
age, male, fam hx, EKG showing LVH

PHASES

Phase I: hospital admission – discharge
Mobilizing early has **better return-to-work rate**
1-2 mets
avoid isometrics (increase afterload) and straight leg raises (increase preload)
precautions: Hold for HR <50 >120, 20 for resting if on beta blocker, SBP should not drop >20
predischarge: submaximal stress test
goal: IADLs, walk 2-3 mph on flat surface x 15-30 min, light housework

Phase II: Outpt training
Cardiac scar forms by 6 weeks post MI
THR determined by ECG: 60-85% of safe maximum
(aerobic conditioning, reacquisition of full activity, risk factor management, lifestyle modification)
Goal: improve VO_2 max, lower HR for given work load, reduce SBP, improved peripheral O_2 extraction and utilization by skeletal muscle, improve depression
Borg scale goal 11-13 (somewhat hard)
May return to sedentary work if walk 3.5 mph comfortable
ETT 6-8 weeks post MI

Phase III: Maintenance 3-9 months
patient monitored continuation of aerobic exercise program, risk-reduction strategies and activity/work modification
Karvonen formula THR = [(HRmax – HR rest) x %intensity] + HR rest

Phase IV: community setting, self-monitors HR or BORG

"Possible contraindications to exercise programs": *American College of Sports medicine*
resting SBP>200 DBP>100
orthostatic BP drop or drop during exercise >20
mod to severe AS
acute systemic illness or fever
Uncontrolled dysrrhythmias, sinus tach (120), CHF
3rd degree AV block, active pericarditis or myocarditis
recent PE, throbophlebitis
resting ST displacement >3mm
uncontrolled DM
orthopedic problems prohibiting exercise

TABLE 9-2. Absolute Contraindications for Entry into Inpatient and Outpatient Exercise Training

- Unstable angina
- Resting systolic blood pressure > 200 mm Hg or resting diastolic blood pressure > 110 mm Hg
- Significant drop (20 mm Hg) in resting systolic blood pressure from the patient's average level that cannot be explained by medication
- Moderate to severe aortic stenosis
- Acute systemic illness or fever
- Uncontrolled atrial or ventricular arrhythmias
- Uncontrolled tachycardia (> 100 bpm)
- Symptomatic congestive heart failure
- Third-degree heart block without pacemaker
- Active pericarditis or myocarditis
- Recent embolism
- Thrombophlebitis
- Resting ST displacement (> 3 mm)
- Uncontrolled diabetes
- Orthopaedic problems that would prohibit exercise

EXERCISE RX: (Braddom)
Modality: lg muscles
Intensity: target HR vs perceived exertion vs METS vs exercise intensity (speed, resistance)
Duration: 20-30 min preceded by warm-up phase and followed by cool-down
Frequency: 3-5 days/week
Rate of progression
Specificity: train muscle groups patient will need in vocation (ie arms for carpenter)

Usual target HR is 85% of maximum HR achieved during ETT
If individual is frail → 60% of max can still achieve training effect
Cardiac transplants and CHF need longer warm up periods
AHA recommends exercise at 40-60% of maximum VO_2 for 20-30 minutes, 3-4 times a week
New Federal recommendation of 60-90 minutes a day

Metabolic Equivalents

1 MET is resting metabolic rate = 3.5 mL O_2/kg/min

Sport Activity	Energy Cost in Mets
Golf	2–5
Bowling	4–5
Volleyball	3–4
Ping pong	3–6
Tennis	4–7
Roller-skating	5–6

Physical Activity Program

Slow walk	2 mph	2–3 mets
Regular speed walk	3 mph	3–4 mets
Brisk walk	3–5 mph	4–5 mets
Very brisk walk	4 mph	5–6 mets
Sexual intercourse*	3–4 mets	
Outdoor work—shovel snow, spade soil		7 mets
Jog, walk	5 mph	9 mets
Mop floor		2–4 mets
Push power lawn mower		4 mets

* **Note:** met level for sexual intercourse varies depending upon reference source. Tardif states that patients who reach 5–6 mets on stress-testing without ischemia or arrhythmias can, in all likelihood, resume their normal sexual activities without any risk. (Tardif 1989)

The goal is the improvement of the cardiovascular capacity through physical exercise training whether in a minimally supervised or unsupervised setting.

Return to Work guidelines by ETT
<5 mets = no return
5-7 mets=household chores and sedentary work
>7 mets = most jobs except heavy industrial labor
5-6 mets = flights of stairs, sex

sex tolerance test = safe if can walk level surface 10 minutes followed by 2 flights of stairs in 10 seconds without symptoms, advise less strenuous positions

Aerobic training program

Increases VO_{2max}, CO, resting stroke volume, workload
Decreases resting HR, resting MVO_2, submax MVO_2
No change in maximum MVO_2 –> determined by anginal threshold (not affected by aerobic conditioning)
No effect on coronary circulation, anginal threshold

ETT

Absolute Contraindications: unstable angina, untreated life-threatening cardiac arrhythmias, uncompensated CHF, advanced A-V block, acute myocarditis/pericarditis, critical AS, severe hypertrophic obstructive cardiomyopathy, uncontrolled HTN 200/110, acute MI, active endocarditis, acute PE, acute systemic illness

Relative Contraindications: significant pulmonary HTN, HTN, tachy/bradyarrythmias, moderate valvular heart disease, moycadial heart disease, electrolyte abnormalities, left main coronary obstruction, hypertrophic cardiomyopathy

BRUCE PROTOCOL

Stage	Grade (%)	Speed (MPH)	Time (min)	Total time (min)
1	10	1.7	3	3
2	12	2.5	3	6
3	14	3.4	3	9
4	16	4.2	3	12
5	18	5.0	3+	15+

Pharmacologic testing in debilitated patients for whom exercise testing cannot be performed, has been used to evaluate ischemia. The data from pharmacologic testing cannot be used in exercise presumption. (Froehlicher 1987)

TABLE 9-4. Contraindications to Exercise Testing

Absolute Contraindications
1. A recent significant change in the resting ECG suggesting infarction or other acute cardiac events
2. Recent complicated myocardial infarction
3. Unstable angina
4. Uncontrolled ventricular dysrhythmia
5. Uncontrolled atrial dysrhythmia that compromises cardiac function
6. 3rd degree A-V block
7. Acute congestive heart failure
8. Severe aortic stenosis
9. Suspected or known dissecting aneurysm
10. Active or suspected myocarditis or pericarditis
11. Thrombophlebitis or intracardiac thrombi
12. Recent systemic or pulmonary embolus
13. Acute infection
14. Significant emotional distress (psychosis)
Relative Contraindications
1. Resting diastolic blood pressure > 120 mmHg or resting systolic blood pressure >200 mmHg
2. Moderate valvular heart disease
3. Known electrolyte abnormalities (hypokalemia, hypomagnesemia)
4. Fixed-rate pacemaker (rarely used)
5. Frequent or complex ventricular ectopy
6. Ventricular aneurysm
7. Cardiomyopathy, including hypertrophic cardiomyopathy
8. Uncontrolled metabolic disease (e.g. diabetes, thyrotoxicosis, or myxedema)
9. Chronic infectious disease (e.g. mononucleosis, hepatitis, AIDS)
10. Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
11. Advanced or complicated pregnancy

Modified from "Guidelines for Exercise Test Administration" In ACSM Guidelines for Exercise Testing and Prescription (5th ed) p.42, 1995, Philadelphia: Lea & Febiger, with permission.

TABLE 9-5. Indications for Stopping an Exercise Test

Symptom-limited maximal test
1. Progressive angina (stop at 3+ level or earlier on a scale of 1–4)
2. Ventricular tachycardia
3. Any significant drop (20 mm HG) of systolic blood pressure or a failure of the systolic blood pressure to rise with an increase in exercise load
4. Light-headedness, confusion, ataxia, pallor, cyanosis, nausea, or signs of severe peripheral circulatory insufficiency
5. 3mm horizontal or downsloping ST depression or elevation (in the absence of other indicators of ischemia)
6. Onset of second- or third-degree A-V block
7. Increasing ventricular ectopy, multiform PVCs, or R on T PVCs
8. Excessive rise in blood pressure: systolic > 250 mm Hg; diastolic pressure > 120 mmHg
9. Chronotropic impairment
10. Sustained supraventricular tachycardia
11. Exercise-induced left bundle branch block
12. Subject requests to stop

Bicycle: better ECG tracing & BP recording, takes up less room
RPP artificially elevated for given VO_2 in alternative testing protocols compared to treadmill (see definitions)

Exercise: **ST depression > 1-2 mm = positive test**
Women have higher likelihood of false positive tests

ECHO STRESS TEST
3 assumptions:
1) induction of ischemia results in area of ventricular dyssynergy
2) wall motion abnormalities are specific for ischemia
3) these wall motion changes can be seen on TTE
Treadmill – echo pre and post
Bicycle – continuous echo

NUCLEAR STRESS - THALLIUM
More accurate than stress echo or ECG alone
Imaging done in conjunction with treadmill
Thallium-201 taken up by cardiac myocytes via NA/K ATPase pump
First pass extraction of 85% and is continuous
Early images – myocardial blood flow
Late images – myocardial viability

PHARMACOLOGIC STRESS
Questionable usefulness for functional eval for exercise Rx
Dipyridamole: induces cardiac stress, may be used with thallium
Coronary artery vasodilator – increases blood flow by 3-5x
Adenosine: more rapid onset due to shorter half life (10-30 seconds)
Dobutamine: causes increased SV and CO
Strong β1, moderate β2, mild α1 stimulation
Raises RPP by ionotropy and chronotropy

LIFESTYLE MODIFICATION
Quitting smoking lowers risk of recurrent cardiac events by 50% in one year and approaches risk of nonsmokers in two years

DEFINITIONS
Heart rate: increases linearly against VO_2 (limited by age)
Maximum HR: max during ETT, estimated by **220-age**

Cardiac Output: increases with increasing work via frank-starling mechanism in late exercise, increased primarily through an increase in ventricular rate (HR)
linear relationship with VO_2

CO=HRxSV

Stroke Volume:
determined by diastolic filling volume which is inversely related to HR
blood ejected with each ventricular contraction, increases w/exercise to become max at 50% over resting basal HR

Maximum aerobic capacity ($VO_{2\ max}$): greatest rate of O_2 consumption a person is able to metabolize, relates directly to max output in watts
VO_2 increases linearly with workload until it plateaus = VO_2max of the individual
total VO_2 provides a measure of the increasing metabolic work of the peripheral skeletal muscles (not the heart)
SV x HR x (A-V O_2 difference)
decreases with age, inactivity, after MI

Aerobic capacity (VO_2): measures work capacity of an individual
Goal is to increase in aerobic training program
While VO_{2max} increases, there is **no change in resting VO_2 or VO_2 at submax workload**

anginal threshold: CO at which myocardial O_2 demand exceeds O_2 delivered

Myocardial oxygen consumption (MVO_2)
linear relationship to VO_2 until anginal threshold
limited by **angina threshold**: point where myocardial oxygen demand exceeds the ability of the coronary circulation to meet that demand,
correlates well with HR and SBP

rate pressure product (RPP) = (HR x SBP)/100

activities with the UE generate higher MVO_2 than LE at same VO_2
activities performed supine as opposed to upright generate a higher MVO_2 at low intensities and lower MVO_2 at higher intensities
activities performed under emotional stress, after smoking, eating, or in cold weather generate a higher MVO_2 at the same VO_2 than activities performed at baseline
activities with higher *isometric* component generate higher MVO_2

SPECIAL POPULATIONS

Amputees

TABLE 9-9

AMPUTATION	% INCREASE	METS
No prosthesis with crutches	50%	4.5
Unilateral BK with prosthesis	9–28%	3.3–3.8
Unilateral AK with prosthesis	40–65%	4.2–5.0
Bilateral BK with prosthesis	41–100%	4.2–6.0
BK plus AK with prostheses	75%	5.3
Bilateral AK with prostheses	260%	11.4
Unilateral hip disartic with prosthesis	82%	5.5
Hemipelvectomy with prosthesis	125%	6.75

(DeLisa JA, Gans BM. Rehabilitation Medicine: Principles and Practice. 3rd ed. Chapter 34 p.1353)

AMPUTEE EXERCISE TEST

- Pharmacological stress testing using dipyridamole—for patients that are unable to perform any exercise stress test
- Upper extremity cycle ergometer stress test—first determine the safety and ability of mobility
- Telemetry monitoring of ambulation training:
  1. Preprosthetic period
  2. Prosthetic period
  3. Postprosthetic period

Elderly:
need longer phase II
HR not best indicator of exercise intensity
Intensity 50-85% MHR
Include warm up and cool down
Low joint impact exercise – alternate UE and LE

Stroke:
Usually occurs within 2 weeks of MI with 60% mortality
Hemiplegic gait increases oxygen consumption (same if walking at **self-selected speed**)
Spasticity can increase BP and HR
Watch for orthostatic hypotension

SCI
Greater risk of CAD: low HDL, glucose intolerance, sedentary
Risk of silent ischemia
dependent edema
may need pharmacologic stress test
reduced SV and CO due to reduced preload (venous pooling)

s/p CABG
excellent candidates
Benefits: increased ischemic threshold, coronary collatorals
Improved LV function, psychologic status
Ameliorated serum lipids
Decreased serum catecholamines, platelet aggregation
ETT can be performed 3-4 weeks after surgery
POD 1 sitting, leg mobilization, OOB
POD 2-5 progressive ambulation and exercise

At home intensity of activity
Low: 2-4 METS, 65-75% THR
Mod: 3-6.5 METS, walk-jog, 70-80% THR
High: 5-8 METS, walk-jog to jog, 75-85%,

If on beta blocker, THR is 20+ rest

Cardiac Transplant
5 & 10 year survival → 82% and 74%
Lose vagal inhibition to SA node, HR 100
Blunted HR response to exercise by 20-25% on ETT
Resting HTN common 2/2 meds

Lose 10-50% of lean body ass decreasing maximum work output and VO_{2max} by 2/3
Increased RPE, minute ventilation, ventilatory equivalent for oxygen
VO2 is the same implying earlier onset of anaerobic metabolism
At max effort, there is lower work capacity, CO, HR, SBP and VO_2

Goal: 60-70% peak effort, 30-60 min, 3-5x/week
Borg 13-14 (somewhat hard to hard)

Cardiomyopathy
Higher risk of sudden death
Earliest finding is limited exercise capacity
Exercise can decrease SV, CO, EF, BP
Prolonged warm ups and cool downs
Dynamic exercise preferable to isometrics
THR should be 10 beats below any exertional endpoint (ie hypotension, significant dyspnea)

Anticoagulation; avoid high impact exercises
Arrythmias: very rare to have

Karvonen Formula for calculating individualized target heart rate parameters:

Target heart rate intensity goal is usually 40-60% (moderate) of the heart rate reserve (HRR) added back to the resting heart rate. See below for example calculation:

Example) A Patient performs Exercise Tolerance Test (ETT) with values as follows:
Maximal heart rate is 160 bpm.
Resting heart rate is 60 bpm.
Heart rate reserve (HRR) = Max HR – Resting HR = 160 bpm - 60 bpm = 100 bpm

Target heart rate for a 40% intensity program would be:
(0.4)(Max HR – Resting HR) + (Resting HR) = (0.4)(100) + 60 = 100 bpm for 40% program

Target heart rate for a 50% intensity program would be:
(0.5)(Max HR – Resting HR) + (Resting HR) = (0.5)(100) + 60 = 110 bpm for 50% program

Target heart rate for a 60% intensity program would be:
(0.6)(Max HR – Resting HR) + (Resting HR) = (0.6)(100) + 60 = 120 bpm for 60% program

Shorthand for a target heart range in a Wellness program prescription would be:
"Target Heart Rate (THR) is 100-120 bpm."

If prescribing a 6-week Cardiopulmonary phase II rehab program, you can use the following format:

Weeks:	Target Heart Rate (intensity)
1-2	## bpm (40%)
3-4	## bpm (50%)
5-6	## bpm (60%)

Hold for BP> (insert max on ETT or highest in vitals trend)
Hold for concerning cardiopulmonary symptoms.
Maintain O2 Sat>91% during exercise with supplemental O2 as needed
May use seated machines (if balance in question)