AAST Acute Care Surgery Didactic Curriculum

Trauma in the Older Adult

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Introduction

Analysis of data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) showed that from 2001 to 2010 of the 175 million U.S. ED visits were by adults older than 65 years despite representing only 13% of the U.S. population (1). Patients with emergency general surgery (EGS) needs comprised 7.1% of all hospitalizations according to the 2012 ACS-NSQIP database of which 50% were older than 60 years of age (2). Havens et al, in a retrospective study utilizing the ACS-NSQIP database, EGS patients tended to be older, mean age of 64 years vs. 59 ($p<0.0001$; and had a significantly higher 30-day mortality rate of 12.50% vs. 2.66%, $p < 0.0001$ compared with the non-EGS patients (3). Nearly half (48.18%) of all EGS patients had a post-operative complication, compared with 27.54% for the non-EGS patients. They concluded that EGS was an independent risk factor for death within 30 days of the index operation (odds ratio [OR], 1.39; 95% confidence interval [CI], 1.03-1.86; p=0.029). It is projected that by 2060, nearly 1 in 4 Americans will be 65 years and older, the number of 85 years and older will triple when the surviving baby boomers will be over 85 years of age (4). This is the population the Acute Care Surgeon cares for the most.

Numerous anatomic and physiologic changes of aging, compounded by chronic disease, impact care of the older patient. There is no opportunity for preoperative testing and risk modification in emergency situations. The discussion in this module is not about specific acute surgical illnesses the general surgeon encounters or individual injuries. Principles of diagnosis and management for individual diagnosis or injury should be the same irrespective of age. The anatomic and physiologic changes mandate a different overall approach to the care of the older adult if the current rate of morbidity and mortality is going to be improved. It is more important for the surgeon to focus on recognizing frailty and not focus on chronological age.

Physiological changes

Aging is a multifactorial process that results in a detrimental decrease in the reparative and regenerative potential in tissues and organs resulting in a reduction in maximal organ function and reserve capacity (5). These changes are determined by genetic, epigenetic and environmental modulators but with different trajectories across organ systems (Fig 1). Therefore, chronologic age may not always match the physiological age. The cumulative effect of multiple organ system deficits, especially in combination with chronic diseases, may lead to a state of frailty. Frailty is a biological syndrome characterized by age-associated decreased homeostatic reserves, resulting in increased vulnerability to stressors such acute illness and injury ((6). As such recognizing frailty is very important in the emergency setting, taking into consideration the severity of the acute illness and the surgical intervention that would be needed. The following is a review of physiological changes in a system-based approach of select organs.

Cardiovascular disease

The incidence and prevalence of cardiovascular disease rise as the segment of the U.S. population 65 years and older increases. The greatest risk in emergency surgery in the older adult is due to cardiac complications. The proportion of admissions with congestive heart failure is shown in Figure 2. Current data show 60%–80% of postoperative deaths following elective procedures are traceable to cardiovascular complications with substantially increased risks of mortality and hospital readmission. The patient should be presumed to have congestive heart failure until proven otherwise.

Physiologic changes of the aging cardiovascular system that the clinician should be aware of are depicted in Table 1. (7).

Cardiac risk stratification for noncardiac surgical procedures.

Level of Risk	Risk Factor
High (cardiac risk often >5%)	Emergency major operations, particularly in elderly patients
	Aortic and other major vascular surgery
	Peripheral vascular surgery
	Anticipated prolonged surgical procedures associated with large fluid shifts and blood loss
Intermediate (cardiac risk generally <5%)	Carotid endarterectomy
	Intraperitoneal and intrathoracic surgery
	Orthopedic surgery
	Prostate surgery
Low (cardiac risk generally <1%)	Endoscopic procedures
	Superficial procedures
	Cataract surgery
	Breast surgery

Aging right ventricle

The RV and LV are connected in series and should be pumping the same SV. Studies using M-mode echo Doppler technology in healthy older adult volunteers, right heart flow may not always equal left heart flow: aging pulmonary vascular resistance. Impaired RV diastolic function attributed to increased RV afterload. Right heart failure patients are preload dependent; they may require fluid resuscitation or diuresis (8). Early echo might be necessary.

Aging left ventricle

Major blood vessels in the systemic and pulmonary circulation have a high elastin content, makes them compliant, distend during systole, and recoil in diastole propelling blood forward. The distensibility dampens the intermittent pumping of the heart to the pulsatile blood flow.

Stiffness of aging blood vessels not only increases the systolic blood pressure but also the workload of the left ventricle resulting in hypertrophy. Seems to be an adaptive response to preserve cardiac function. Diastolic blood pressure is lower due to a more rapid pressure decrease in diastole. A widened pulse pressure is observed.
It should be noted that a normal ejection fraction does not rule heart disease. Studies have shown that increasing age was associated with a decrease in LVEDV and LVESV by echocardiography (9). Cheng et al, demonstrated LVEDV and LVESV progressive decline with advancing age due age-related structural remodeling using cardiac MRI among 5,004 healthy volunteers without significant cardiovascular disease (10). They note that hypertrophy does not mean an increase in functional mass, as there is a depletion in myocyte number and increased collagen deposition. Multiple diseases may cause HF within any particular EF range. Patients will seem normal at rest and this resting EF is often erroneously used in these patients as a surrogate for achievable cardiac performance under stress. Also, inotropic agents will alter the echo findings significantly from baselines measured before the patient got sick by increasing the EF. When assessing LV systolic function 2DE or 3DE should be routinely used and calculating the EF from EDV and ESV (9). LV EFs of <52% for men and <54% for women are suggestive of abnormal LV systolic function.
Be careful with diuresis, inotropic support, rule-out mitral regurgitation, and aortic stenosis.

The effect of aging on the β-adrenergic response
The normal response of the cardiovascular system to stress from injury or surgery is to increase cardiac output by increasing heart rate and myocardial contractility via the sympathetic nervous system. Sudden changes in systemic blood pressure activate the baroreceptors, which in turn modify the activity of the autonomic nervous system. Stimulation of chemoreceptors increases ventilatory rate and depth ((11). Decreased responsiveness to β-adrenergic receptor stimulation in cardiomyocytes, decreased reactivity to baroreceptor and chemoreceptor output with age has been demonstrated. Whereas in young healthy individuals' cardiac output is maintained by increasing heart and contractility, in the older adult there is a tendency to have increased ventricular filling volume (preload). Because of the dependence on preload, even minor hypovolemia can result in significant compromise in cardiac function.
Anticoagulants and antiplatelet agents are other drugs are encountered in patients who have undergone prior treatment for cardiac or vascular disease. ACC/AHA guidelines should be followed. Three questions must be included in the history--why the patient is on the medication, what was the event leading to the prescription and when the last dose was. ACC/AHA Guidelines on management of patients with coronary stents are shown in Figure 3.

Pulmonary
The primary role of the lung is gas exchange, movement of O_2 into the body and removal of CO_2 from the body. Mechanical properties of the lung and chest wall influence air movement and the health of respiratory membrane affects O_2, and CO_2 exchange.

Calcifications of the costochondral joints and thoracic vertebral articulations result in decreased compliance and elastic recoil of the chest wall. Respiratory muscle weakness may occur due to sarcopenia (age-associated muscle loss). In the face of decreased elastic recoil, the surface area available for gas exchange is decreased (increased anatomic dead space) as alveolar ducts enlarge. Functional residual capacity (FRC) decreases as a result of the fall in the entire respiratory system compliance. Forced vital capacity (FVC) declines 0.15-0.30 L per decade, and the forced expiratory volume in one-second (FEV1) also decreases. Although hypoxemia does not typically occur, diffusion capacity decreases by about 5% per decade (5). This may be due to a combination of age-related decrease in the arterial PaO2, about 4 mmHg per decade due to increased thickness of the respiratory membrane, and decreased surface area from nearly 75 m^2 at age 20 to about 60 m^2 by age 60.
The closing volume, the lung volume at which small alveoli collapse, increases with age resulting in increased residual volume by about 10% per decade. When closing volume increases, functional residual capacity (FRC) decreases. FRC keeps small airways open. The net effect is the creation of V/Q mismatch and risk of hypoxemia. Diseases such as asthma, chronic obstructive pulmonary disease, and pulmonary edema also have the same effect as the small airways collapse during exhalation, leading to air trapping and atelectasis. The central drive to the respiratory muscles in response to hypoxemia, hypercapnia, and mechanical load is decreased. Collectively, these changes increase susceptibility to mucous plugging and pneumonia.

COPD from smoking, long term environmental exposures (biomass fuel smoke or other air pollution), and genetics increases with age making it very prevalent with in the older adult population. The work of breathing is increased secondary to airflow obstruction and exhalation no longer is passive but instead requires active, expiratory muscle contraction. Physiological dead space is increased as well; therefore, the tidal volume must increase to maintain the same level of alveolar ventilation.

Rib fractures are very common due to falls and pose a significant risk of pneumonia and death in the older adult. Pain leads to a decrease in tidal volume and inability to cough effectively. Presence of flail segments may create paradoxical chest wall movement which further decreases effective ventilation increasing the risk of pneumonia and death. Goldberg and Malhotra highlight certain principles of pulmonary care that should be applied in hospitalized older adult patients (12):

A) Optimizing gas exchange:

   1. Preventing atelectasis

   (a) Raising the head of the bed to 30°: spontaneous tidal volumes are lower in supine positions than those in an upright position

   (b) Incentive spirometry

   2. Providing adequate analgesia while minimizing sedation: consider TAP blocks in abdominal operations. A multimodal approach to analgesia is optimal without the use of high doses of narcotics

   3. Pulmonary hygiene: respiratory therapy

B) Preventing aspiration:

Aspiration is a common cause of respiratory failure and may be lethal. Risk factors contributing to aspiration include the positioning of the head of the bed $<30°$, presence of a nasogastric tube, enteral feeds (especially via a nasogastric tube), mechanical ventilation longer than 7 days, Glasgow Coma Score less than 9, and thermal injury

C) Prevention of pulmonary infections: mechanisms for clearing infected material from the upper airways – mucociliary escalator, cough reflex, etc. Have diminished function with age, making the geriatric patient more prone to the development of a pulmonary infection. The problem is more pronounced in the mechanically ventilated patient as the protective mechanisms are completely eliminated, therefore making extubation a priority. Postpyloric feeding is associated with a lower incidence of ventilator associated pneumonia.

i. Early detection of deterioration
ii. Early detection of pulmonary infections and prompt treatment
iii. Assistance with ventilation if required; non-invasive or intubated ventilation
iv. Weaning strategy
v. Role of tracheostomy
vi. Ethical considerations and end-of-life care

Pain control is important if early mobilization is to occur, a TAP block should be considered in abdominal surgery

Renal

There is a reduction in renal mass with aging, causing a decrease in the number of functional glomeruli. As such there is a decrease in glomerular filtration rate (GFR) of 30% to 40% by the age of 80 years (13). The kidneys develop diffuse glomerulosclerosis with age (up to 30% by age 70. Serum blood urea nitrogen (BUN) and creatinine (Scr) are used as markers of renal function; they are, however, less accurate in the older adult than in a younger person. Due to the reduced lean body mass, the measured serum creatinine (Scr) decreases. Creatinine clearance decreases 7.5–10 mL per decade on average but with a large variance. Scr may, however, remain constant due to the decreased lean body mass. Also, a low Scr may be a manifestation of severe protein-calorie malnutrition. Fluid resuscitation may also dilute the Scr from a high baseline giving the impression of a normal function. These parallel changes make interpretation of serum creatinine difficult and should be done with caution. A snapshot of the actual GFR can be estimated using the Cockcroft–Gault formula:

Creatinine clearance = $[(140 - \text{age})(\text{weight in kg})]/(72 \times \text{Scr})$

(Arithmetic result × 0.85 = clearance for female patients)

It has been suggested that cystatin C may be a more accurate renal function marker in the older adult (5) and electrolyte balance is well maintained but the ability to acidify urine and excrete an acid load is decreased.

The RIFLE criteria (Risk, Injury, Failure, Loss, and End-stage Kidney) should be routinely used, and an early nephrology consultation when AKI is suggested Table 2. A critical care pharmacologist can also assist in clarifying renal-active medication issues in these complex patients. Avoid nephrotic drugs, hypovolemia, intravenous contrast, and hyperglycemia

Gastrointestinal

The gastrointestinal system (GI) has other roles it plays although the main function is digestion and absorption of nutrients. There is direct exposure to the environment through microorganisms and toxins ingested with food. The GI system is a complex defense comprising of the innate immune system. Although the GI function is relatively preserved with aging decline in digestion and absorption of nutrients, innate immunity, etc. does occur. Dysphagia, GERD, and constipation often are common, a result of neurodegeneration of the aging enteric nervous system. Gastric emptying and motility are decreased.

Nutrition

Malnutrition affects approximately 50% of critically ill patients and independently predicts poor clinical outcomes. Hospitalized patients with malnutrition experience a 4-fold higher risk of mortality than well-nourished patients (14). Although gastrointestinal function is relatively preserved with aging, the catabolic state induced by critical illness or injury can lead to rapid muscle breakdown. Protein-deficient malnutrition develops more rapidly in the older adult, Impaired nutrition is related to an increased mortality in older patients requiring mechanical ventilation and is an independent risk factor for infection, impaired wound healing, and longer ICU stays. Early screening should be part of routine using various tools available, the Nutric Score and sarcopenia index [(serum creatinine/serum cystatin C)*100] Early and sufficient nutritional support reduces hospital length of stay, mechanical ventilation days, and results in improved outcomes.

Neurologic function

Cognitive decline with aging is multifactorial, cerebral tissue atrophy, decrease in cerebral blood flow and brain oxygen consumption can manifest as blunted sensation (visual, auditory, and tactile), altered cognition, and blunted pain perception. Alterations in cerebellar function, gait, balance, and vision increase the risk of injury, especially falls. Delirium in acute illness, especially in the intubated patients in the intensive care unit, should be recognized as an acute form of organ dysfunction (15). Usually manifests as a rapidly developing disturbance of both consciousness and cognition. Delirium has been shown to be an independent predictor of higher 6-month mortality in patients receiving mechanical ventilation (16). Assume that many of the patients will have some degree of delirium/encephalopathy post-operatively and probably will have limited or no capacity for complex decision making. Henceforth the need to identify next-of-kin or health-care-power of attorney to help with decision-making.

Schwab and Kauder described an age-group approach although trauma patients, that is applicable in emergency general surgery (17).

Treatment Axioms, 65 Through 74 Years

1. Accept the presence of age-related and acquired disease induced physiologic alterations of organ systems
2. Accept the presence of acquired diseases and medications to correct or control them; assume a higher incidence of previous surgery and transfusion
3. Decide whether the patient is competent to give a reliable medical history; review the history as soon as possible with the patient's relatives or personal physician
4. Aggressively monitor the patient and control the physiologic characteristics to optimize cardiac performance and oxygen metabolism
5. Assume that any alteration in mental status or cognitive or sensory function indicates the presence of a brain injury; imaging of the brain is mandatory
6. Proceed with standard diagnostic and management schemes, including early, aggressive operative management
7. Be aware of poor outcome, especially with severe injury to the central nervous system or marked physiologic deterioration secondary to injury; check for advance directives

Treatment Axioms, 75 Years or Older

1. Proceed as in items 1 through 5 for patients 65 through 74 years of age
2. Assume a poor outcome with moderately severe injury, especially in the central nervous system or for any injury causing physiologic dysfunction
3. After aggressive initial resuscitation and diagnostic maneuvers, examine item 2 and discuss appropriateness of care with the patient (if competent) and family members
4. Attempt to be humane and recognize the legal and ethical controversies involved; consider early consultation of experts in ethics and social services to help the family and medical team with difficult decisions.

ACS/NSQIP has compiled the Best Practices Guidelines on the Optimal Perioperative Management of the Geriatric Patient. Although it mainly focuses on elective surgery, there are important points that are applicable to emergency situations.

1. The health care team (including the surgeon and anesthesiologist) should ensure that they discuss personal goals and treatment preferences prior to surgery, including specific outcomes that may be important to older adults, such as postoperative functional decline, loss of independence, and skilled care burden.
2. The health care team (including the surgeon and/or anesthesiologist) should ensure that older adult patients undergoing surgery have an advance directive and a designated health care proxy (or surrogate decision-maker). This information should be documented in the patient’s medical record.
3. Whenever possible, the health care team should consider early (postoperative) palliative care consultation in older adult patients with poor prognoses undergoing surgery, especially those not expected to survive more than six months postoperatively.

Pre-op evaluation.

Perioperative risk assessment is important in every aspect of surgical planning although maybe limited in emergency settings. The primary goal is to gauge the patient's risk for postoperative complications and death. A carefully done history, physical examination, and laboratory data can identify high-risk surgical patients and gauge the functional status prior to the illness or injury (18). The ACS recommends a four-question survey of activities of daily living (ADLs) as a screen to identify unsuspected functional compromise in geriatric patients. Patients with a good functional status have a low risk of perioperative cardiovascular complications. One such measure obtained from the H/P is the metabolic equivalents (METs) with 1 MET defined as the amount of oxygen consumed while sitting at rest and equal to 3.5 mL O2 uptake/kg/min (19). A high prohibitive operative risk should be identified and goals of care discussions with the patient and family should ensue. A patient can be saved from an inappropriate operation or may choose modification of the operative plan. The ACS NSQIP calculator is a good tool to aid the discussion, is available: https://riskcalculator.facs.org/RiskCalculator/.
Given the higher rate of serious complications, loss of independence (especially when discharged to an Extended Care Facility) and death in many frail and older patients, shared decision-making (SDM) to present options is a best-care practice. Communication and partnership between surgeons, patients and families can help patients make treatment decisions based on what is important to them and avoid arduous interventions near end of life. Explaining the risks to the patient and family can be a difficult task, scenario planning with best case/worst case framework has been shown to be a useful strategy and can be helpful in these types of situations (20).

MET (Metabolic equivalent of task) can be useful

MET Scale	
Less than 4 METs	• Self care of oneself • Eat, dress, use toilet • Walk indoors around the house • Walk 1 to 2 blocks on ground level at 2 to 3 mph
4 METs	• Climb a flight of stairs or walk up a hill • Walk on level ground at 4 mph • Do light yard work
6 METs	• Do heavy work around the house like scrubbing floors or moving furniture • Do moderate yard work
8 METs	• Participate iin moderate recreational sports • Daily exercise program • Do heavy yard work
10 METs	• Participate in strenuous sports • Prolonged aerobic exercise

Excellent functional status,>10 METs; good, 7 to 10 METs; moderate, 4 to 6 METs; and poor, <4 METs. The risk is increased if unable to perform at a level of 4 METs.
Because there is no time for a thorough pre-operative optimization, attention should be focused on identifying quickly correctible deficiencies.

Checklist:

Pre-op

1. Check volume status:
    a. Alertness, delirium?
    b. Mucous membranes
    c. BP, HR (is the patient on a B-blocker?)
2. A baseline EKG, BMP
3. Admit patient to the ICU if there is time for pre-op resuscitation. The only patient that has to go to the OR now is exsanguinating hemorrhage.
4. Bedside intensivist-performed echo: can be very useful to get a global view of the heart structure and IVC size and collapsibility.
5. Secure IV access
6. Discuss surgical plan with anesthesiologist.
7. Patients on beta-blocking drugs, statins, or both should be continued during and after the perioperative period, with dose or adjustments as necessary

Medications known to reduce risk of cardiac events in surgical patients include aspirin, β-blocking agents, and statin drugs should be continued in patients that are already on these medications.

Anticoagulants and antiplatelet agents in emergency situations should be determined by a consensus of the surgeon, anesthesiologist, cardiologist, and patient, who should weigh the relative risk of bleeding with that of stent thrombosis

I**ntraaop:**

Intra-op hemodynamic monitoring

Practice damage control surgery principles:

1. Abbreviated surgery
2. Damage control resuscitation
3. Communicate with the anesthesiologist surgical plan, extubate or not extubate

Post-op

Close monitoring:

Respiratory: O2 saturation, use of accessory muscles ((21)

Hemodynamics: BP, HR (is the patient on a B-blocker?), urine output

Special attention is warranted in patients with a known history of chronic obstructive pulmonary disease (COPD), asthma, upper respiratory tract infections, pneumonia, or other pulmonary conditions. A preoperative CXR, a quick respiratory therapy in the ER or pre-op with inhaled bronchodilators inhaled anticholinergic (e.g., ipratropium) and inhaled beta agonists as needed. Prophylactic glucocorticoids are only required if the patient is being maintained on systemic or high dose inhaled steroids. In patients at high risk for perioperative pulmonary complications. A laparoscopic surgical option should be utilized over open surgery if possible. A TAP block would also be advantageous. Early postoperative mobilization and respiratory therapy to increase lung expansion should be implemented to the degree it is possible.

The duration of delirium has been linked to increased mortality (21), strategies to prevent and treat delirium when it occurs must be addressed.

Delirium varies from patient to patient; treatment strategies should be individualized. But in general, three risk factors in particular—sedatives, immobility and sleep disruption prevalent in the ICUs should be addressed. The ABCDEF bundle:

A: Assess, Prevent and Manage Pain

B: Both SATs and SBTs

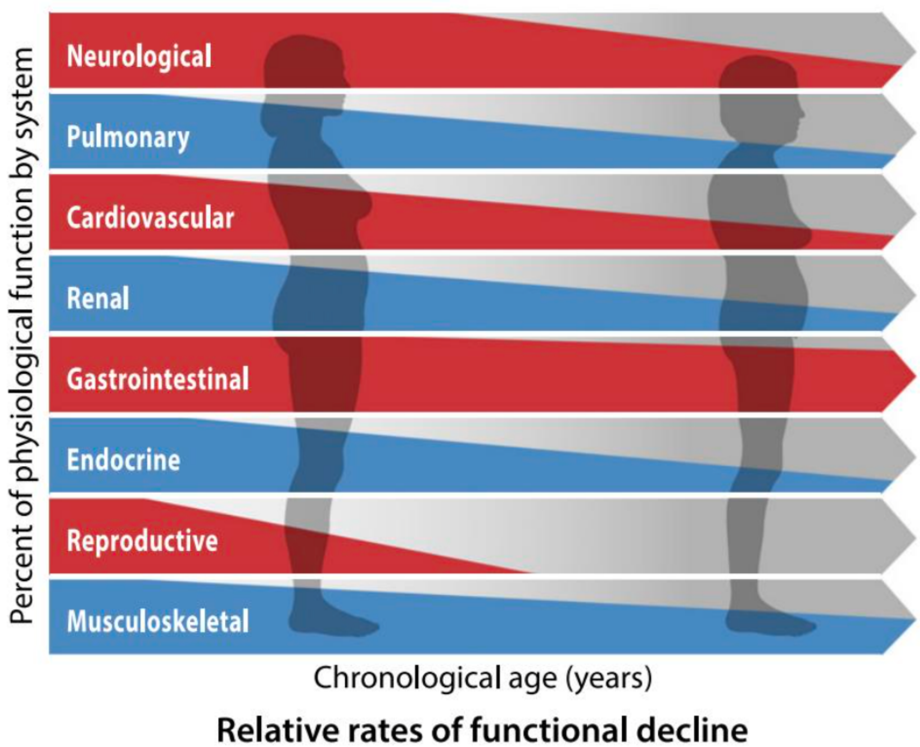
C: Choice of Sedation

D: Delirium: Assess, Prevent and Manage E: Early Mobility and Exercise

F: Family Engagement and Empowerment

Appendix

Figure 1



Relative rates of decline of organ-specific physiological function. Different organ systems may carry a specific vulnerability to age.

Khan, eta al. Molecular and physiological manifestations and measurement of aging in humans, Aging Cell (2017) 16, pp624–633

Figure 2

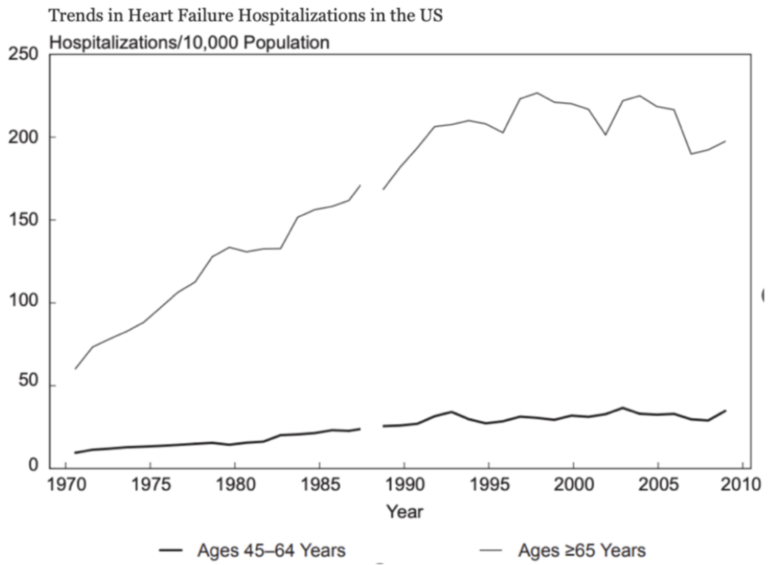
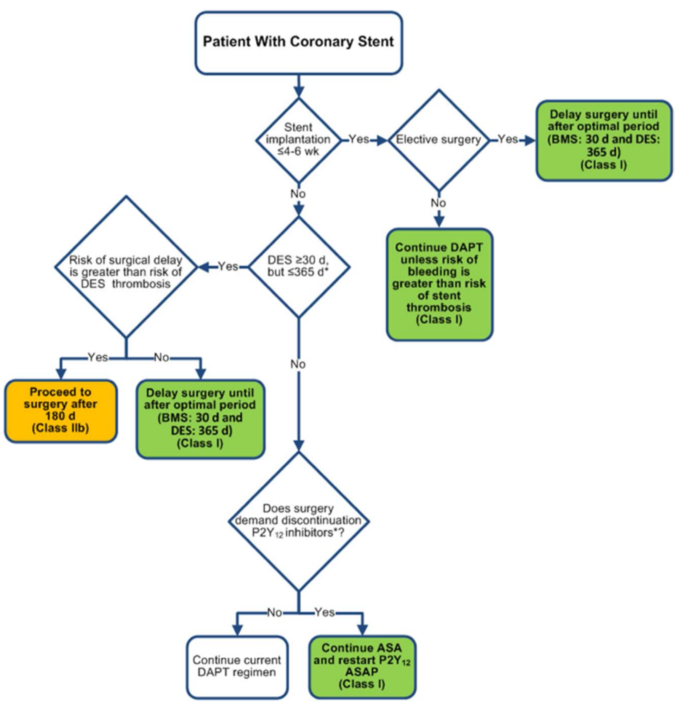


Figure 3



Algorithm for antiplatelet management in patients with PCI and non-cardiac surgery.
*Assuming patient is currently on DAPT (dual antiplatelet therapy).
BMS (bare- metal stent); DES (drug-eluting stent) and PCI (percutaneous coronary intervention)

Table 4. Duke Activity Status Index

Activity	Weight
Can you…	
1. take care of yourself, that is, eating, dressing, bathing, or using the toilet?	2.75
2. walk indoors, such as around your house?	1.75
3. walk a block or 2 on level ground?	2.75
4. climb a flight of stairs or walk up a hill?	5.50
5. run a short distance?	8.00
6. do light work around the house like dusting or washing dishes?	2.70
7. do moderate work around the house like vacuuming, sweeping floors, or carrying in groceries?	3.50
8. do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?	8.00
9. do yardwork like raking leaves, weeding, or pushing a power mower?	4.50
10. have sexual relations?	5.25
11. participate in moderate recreational activities like golf, bowling, dancing, doubles tennis, or throwing a baseball or football?	6.00
12. participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?	7.50

Reproduced with permission from Hlatky et al.[133]

American Society of Anesthesiologists (ASA) Physical Status Classification		
ASA	Definition	Examples
ASA I	A normal healthy patient	Healthy, nonsmoking, no or minimal alcohol use
ASA II	A patient with mild systemic disease	Mild diseases only without substantive functional limitations. Current smoker, social alcohol drinker, pregnancy, obesity (30 < BMI < 40), well-controlled DM/HTN, mild lung disease
ASA III	A patient with severe systemic disease	Substantive functional limitations; one or more moderate to severe diseases. Poorly controlled DM or HTN, COPD, morbid obesity (BMI ≥40), active hepatitis, alcohol dependence or abuse, implanted pacemaker, moderate reduction of ejection fraction, ESRD undergoing regularly scheduled dialysis, history (>3 mo) of MI, CVA, TIA or CAD/stents
ASA IV	A patient with severe systemic disease that is a constant threat to life	Recent (<3 mo), MI, CVA, TIA or CAD/stents, ongoing cardiac ischemia or severe valve dysfunction, severe reduction of ejection fraction, shock, sepsis, DIC, ARD, or ESRD not undergoing regularly scheduled dialysis
ASA V	A moribund patient who is not expected to survive without the operation	Ruptured abdominal/thoracic aneurysm, massive trauma, intracranial bleed with mass effect, ischemic bowel in the face of significant cardiac pathology or multiple organ/system dysfunction

Comparison of Perioperative Risk Calculators

	Goldman Index of Cardiac Risk (1977)	Revised Cardiac Risk Index (1999)	NSQIP Perioperative MI and Cardiac Arrest (MICA) Risk Calculator (2011)	NSQIP Universal Surgical Risk Calculator (2013)
Criteria	• Jugular venous distention or a third heart sound on auscultation • Recent MI within 6 mo • ≥5 PVCs per min • Nonsinus cardiac rhythm or PACs on preoperative ECG • Age >70 • Aortic stenosis • Intraperitoneal, intrathoracic, or aortic surgery • Any emergency surgery	• Cerebrovascular disease • Ischemic heart disease • History of congestive heart failure • Insulin therapy for diabetes mellitus • Serum creatinine ≥2.0 mg/dL • Planned high-risk procedure (intraperitoneal, intrathoracic, or vascular surgery)	• Age • ASA class • Creatinine • Preoperative function • Procedure type (anorectal surgery, aortic, bariatric, brain, breast, cardiac, ENT, foregut/hepato-pancreatobiliary, gallbladder/appendix/adrenal/spleen, intestinal, neck, obstetric/gynecologic, orthopedic, other abdomen, peripheral vascular, skin, spine, thoracic, urology, vein)	• Age group, y • Sex • Functional status • Emergency case • ASA class • Steroid use for chronic condition • Ascites within 30 d preoperatively • System sepsis within 48 h preoperatively • Ventilator dependent • Disseminated cancer • Diabetes mellitus • Hypertension requiring medication • Previous cardiac event • Congestive heart failure in 30 d preoperatively • Dyspnea • Current smoker within 1 y • History of COPD • Dialysis • Acute renal failure • BMI class • CPT-specific linear risk
Outcome	Intraoperative/postoperative MI, pulmonary edema, VT, cardiac death	MI, pulmonary edema, ventricular fibrillation, complete heart block, cardiac death	Intraoperative/postoperative MI or cardiac arrest within 30 d	Cardiac arrest, MI, all-cause mortality within 30 d
Derivation set ROC	0.61	0.76	0.88	0.90 (cardiac arrest or MI) 0.94 (mortality)
Validation set ROC	0.701	0.806	0.874	Not reported

ASA indicates American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CPT, Current Procedural Terminology; ENT, ear nose and throat; MI, myocardial infarction; NSQIP, National Surgical Quality Improvement Program; ROC, area under the receiver operating characteristic curve (C statistic); PAC, premature atrial contractions; PVC, premature ventricular contraction; and VT, ventricular tachycardia.

Six independent risk predictors for the revised cardiac risk index	
Patients with two or more risk factors are considered elevated risk	
1	High-risk type of surgery (intraperitoneal, intrathoracic, suprainguinal vascular surgery)
2	History of ischemic heart disease
3	History of congestive heart failure
4	History of cerebrovascular disease
5	Insulin therapy for diabetes
6	Preoperative serum creatinine >2 mg/dL

Classes 1 to 3 (0–2 points) low-to-intermediate-risk, Class 4 (3 or more points) high-risk.

Approach to Bridging Therapy.

Condition	Bridging Therapy Required	No Bridging Therapy	Comments
Mechanical heart valve	Mitral-valve replacement, two or more mechanical valves, non-bileaflet aortic-valve replacement, or aortic-valve replacement with other risk factors	Aortic-valve replacement, bileaflet prosthesis, and no additional risk factors	Other risk factors include prior stroke, TIA, intracardiac thrombus, or cardioembolic event
Nonvalvular atrial fibrillation	Prior stroke or embolic event, cardiac thrombus, or $CHADS_2$ score of ≥4	No prior stroke or embolic event, absence of cardiac thrombus, or $CHADS_2$ score of <4	Prior stroke, TIA, intracardiac thrombus, or cardioembolic event increases risk
Venous thromboembolism	Venous thromboembolism within previous 3 mo or severe thrombophilia	Venous thromboembolism >3 mo previously or no additional risk factors (e.g., active cancer and nonsevere thrombophilia)	Consider inferior vena cava filter if venous thromboembolism occurred <1 mo previously, if urgent or emergency surgery is required, or if there is a contraindication to anticoagulation therapy

Suggested approach to bridging heparin therapy for patients on chronic anticoagulant therapy. Reproduced from Baron and coauthors[20] with permission.

Tables

Table 1

Cardiovascular Element	Alteration in the Elderly
Right ventricle	Reduced systolic function Reduced diastolic function
Left ventricle	Left ventricular hypertrophy Dependence on atrial contribution Age-related impaired contractility and relaxation
Vascular structures	Increased arterial stiffness Systolic hypertension
Cardiac output	Preserved resting cardiac output Preserved ejection fraction
Changes in physiology	Blunted baroreceptor reflex Decreased adrenergic responsiveness
Response to stress	Decreased reliance on heart rate Increased cardiac output due to increased stroke volume

From: Martin, et al, Effect of Aging on Cardiac Function Plus Monitoring and Support, Surg Clin N Am 95 (2015) 23–35 http://dx.doi.org/10.1016/j.suc.2014.09.010

Table 2

Risk, Injury, Failure, Loss of kidney function and End-stage kidney disease (RIFLE) classification

Class	GFR	UO
Risk	↑ SCr × 1.5 or ↓ GFR >25%	<0.5 mL/kg/h × 6 h
Injury	↑ SCr × 2 or ↓ GFR >50%	<0.5 mL/kg/h × 12 h
Failure	↑ SCr × 3 or ↓ GFR >75% or if baseline SCr ≥353.6 μmol/L(≥4 mg/dL) ↑ SCr >44.2 μmol/L(>0.5 mg/dL)	<0.3 mL/kg/h × 24 h or anuria × 12 h
Loss of kidney function	Complete loss of kidney function >4 weeks	
End-stage kidney disease	Complete loss of kidney function >3 months	

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