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Risk Factors and Prevention Strategies of Perioperative Myocardial Injury in Elderly Patients with Complex Coronary Artery Lesions Undergoing Interventional Therapy

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Abstract

The incidence and clinical risks of perioperative myocardial injury are high in elderly patients with complex coronary artery lesions receiving interventional therapy. This paper analyzes the core risk factors from three dimensions: patients' basic conditions, coronary lesion characteristics, and surgical operations, and elaborates the internal pathogenesis, including microcirculation disturbance, ischemia-reperfusion injury, inflammatory response, and oxidative stress. A full-process management system covering precise preoperative evaluation and pretreatment, standardized intraoperative operation and microcirculation protection, as well as close postoperative monitoring and complication intervention, was established, which is implemented through multidisciplinary whole-course nursing. In accordance with the latest guidelines and consensus, individualized medication regimens, surgical schemes, and rehabilitation plans were optimized. This study provides clinical references for preventing perioperative myocardial injury and improving the efficacy of interventional therapy in elderly patients.

Keywords

Elderly patients; complex coronary artery lesions; interventional therapy; perioperative myocardial injury; prevention and control strategies

1. Core Risk Factors

Perioperative myocardial injury is one of the most common severe adverse cardiovascular events in elderly patients with complex coronary artery disease after percutaneous coronary intervention (PCI). It significantly increases the risks of short-term and long-term cardiovascular mortality, prolongs hospital stay, and impairs long-term quality of life. The physiological function decline in the elderly, complex anatomical characteristics of coronary lesions, and invasive stimulation during interventional surgery interact with each other, leading to multiple causes of perioperative myocardial injury. Systematic sorting out risk factors from individual basic status, anatomical and pathological features of coronary lesions, and clinical surgical procedures can provide an important basis for early identification of high-risk populations and formulation of individualized intervention measures.

1.1 Patients' Basic Factors

Advanced age is an independent major risk factor for perioperative myocardial injury, and patients aged ≥75 years are defined as a high-risk population. With aging, elastic fibers in coronary vascular walls gradually decrease, smooth

muscle cells become stiff and prone to thrombosis, and vascular regulation and endothelial protective functions decline. Meanwhile, elderly patients are often accompanied by a chronic low-grade inflammatory state and excessive accumulation of oxygen-free radicals, which further aggravate vascular damage. Cardiac function is closely correlated with perioperative myocardial injury. Patients with severe cardiac insufficiency with left ventricular ejection fraction (LVEF) <40% have insufficient myocardial reserve and low tolerance threshold [1]. Intraoperative operations easily induce myocardial ischemia, and hemodynamic changes may cause hypotension and coronary slow flow, further reducing myocardial perfusion and triggering myocardial injury or even necrosis.

Renal insufficiency is a common comorbidity in elderly patients, which is evaluated by estimated glomerular filtration rate (eGFR). Renal dysfunction leads to the accumulation of metabolic wastes, damages cardiomyocytes, and increases the incidence of contrast-induced nephropathy. The vicious cycle between contrast-induced renal injury and myocardial injury elevates the risk of perioperative myocardial injury. Diabetes mellitus, a systemic metabolic disease, damages blood vessels and myocardium. Long-term hyperglycemia destroys vascular endothelium, causes myocardial microcirculation perfusion disorder, activates the coagulation system, and inhibits fibrinolysis, thus increasing thrombotic risk. The risk of perioperative myocardial injury in elderly diabetic patients is 1.5-2 times higher than that in non-diabetic elderly patients. Long-term hypertension and hyperlipidemia increase cardiac burden and coronary artery damage: hypertension causes vascular wall remodeling and sclerosis, while hyperlipidemia contributes to unstable plaque formation, and intraoperative stimulation easily induces embolism and myocardial injury. In addition, elderly patients often suffer from frailty and low body weight; those with body weight less than 60 kg are prone to drug metabolic disorders, elevated bleeding risk, and poor myocardial repair ability, resulting in aggravated clinical conditions.

1.2 Characteristics of Coronary Artery Lesions

Complex coronary artery structure in elderly patients is an important predisposing factor for perioperative myocardial injury. High-risk lesions for interventional therapy include left main coronary artery lesions, coronary bifurcation lesions, severe calcified lesions, diffuse long lesions over 20 mm, and multi-vessel diffuse lesions [2]. Such lesions are characterized by tortuous blood vessels, severe stenosis, and wide involved ranges, bringing great difficulties in guide wire passage, balloon pre-dilation, and stent implantation during surgery. These procedures easily cause vascular endothelial injury, vasospasm, and local ischemia, increasing the possibility of myocardial injury.

The pathological properties of coronary plaques affect the risk of perioperative cardiovascular events. Vulnerable plaques with large lipid cores and thin fibrous caps are unstable. Mechanical compression and traction during interventional therapy may lead to plaque rupture and shedding of debris, forming microemboli that disturb myocardial microvascular blood supply and induce occult myocardial injury. Patients with acute coronary syndrome or high intracoronary old thrombus burden have complex and loose intracoronary thrombus components, which are prone to shedding and diffusion during operation, causing microcirculation embolism and increasing the incidence of no-reflow and slow flow, serving as the pathological basis of perioperative myocardial injury. Meanwhile, most elderly patients with complex coronary lesions have poorly developed coronary collateral circulation. Insufficient collateral blood flow cannot effectively compensate for transient ischemia during main vessel surgery, thus exacerbating ischemia-reperfusion injury and inducing perioperative myocardial injury.

1.3 Surgical Operation Factors

Higher complexity and greater trauma of interventional surgery are associated with a higher incidence of perioperative myocardial injury. Implantation of more than 3 stents or a single stent longer than 30 mm combined with high-risk lesion pretreatment leads to extensive and severe mechanical damage to vascular endothelium, intensifies inflammatory stress response, and increases the risk of cardiomyocyte injury. Complex operations prolong operative time, increase vascular stimulation, disrupt coronary hemodynamic homeostasis, and cause myocardial ischemia and hypoxia.

Intraoperative vascular dissection and side branch occlusion are operation-related risk factors for focal myocardial injury. Balloon dilation and stent deployment in main vessels may cause intimal dissection and impair blood perfusion; stent implantation in main vessels during bifurcation lesion treatment may compress and occlude branch vessels, resulting in myocardial ischemia and injury in corresponding blood supply areas, and even perioperative myocardial infarction in severe cases [3]. No-reflow and slow flow are common intraoperative microcirculation disorders caused by plaque debris, thrombotic microemboli, microvascular spasm, and endothelial edema, with an incidence of 10%-30%. Under such conditions, epicardial coronary arteries remain unobstructed, while myocardial microcirculation

perfusion is destroyed, which is the direct cause of perioperative myocardial injury. Excessive contrast agent dosage also cannot be ignored; dosage exceeding 3 ml/kg body weight increases toxicity to kidneys and cardiomyocytes, destabilizes cardiomyocyte membranes, induces microcirculation disturbance, and causes myocardial damage.

2. Main Pathogenesis

Perioperative myocardial injury in elderly patients with complex coronary artery lesions results from the combined effect of multiple pathological mechanisms, and clarification of these mechanisms is the premise for formulating targeted prevention and control strategies [4].

Microcirculation disturbance is the core pathogenesis. Intraoperative microemboli lead to microvascular embolism, and surgical stress induces microvascular spasm, endothelial cell swelling, and luminal stenosis, ultimately causing no-reflow, cardiomyocyte damage, and necrosis. Ischemia-reperfusion injury plays a major role in aggravating myocardial injury after recanalization of occluded coronary arteries. Blood flow restoration triggers the explosive release of oxygen-free radicals, which damage cardiomyocyte structures and induce calcium overload, further activating inflammatory cells and promoting the release and diffusion of inflammatory factors. Ischemia caused by side branch occlusion and vascular dissection is another mechanism of focal myocardial injury. Main vessel interventional operations easily lead to side branch ostial occlusion, and vascular dissection reduces distal blood perfusion, resulting in myocardial ischemia and cardiac dysfunction. In addition, excessive inflammatory response and oxidative stress are key pathogenic mechanisms [5]. Elderly patients and those with underlying diseases have elevated baseline inflammatory and oxidative stress levels; interventional surgery further activates inflammatory pathways, increases inflammatory factor secretion, and disrupts antioxidant systems, forming a vicious cycle of inflammation, oxidative stress, and myocardial injury.

3. Systematic Prevention and Control Strategies

Based on the risk factors and pathogenesis of perioperative myocardial injury, a full-process integrated prevention system covering preoperative, intraoperative, and postoperative periods should be established. In accordance with the physical conditions and lesion complexity of elderly patients, precise evaluation, individualized intervention, standardized surgical operation, and full-scale complication management should be implemented, and multidisciplinary collaboration and comprehensive geriatric assessment should be adopted to fully carry out prevention and control measures.

3.1 Preoperative Stage: Precise Evaluation and Individualized Pretreatment

Preoperative high-risk screening is the primary step to identify patients at high risk of myocardial injury, and essential examinations shall be completed in accordance with clinical guidelines [6]. High-sensitivity cardiac troponin, high-sensitivity C-reactive protein, and N-terminal pro-B-type natriuretic peptide (NT-proBNP), recommended as Class II evidence in the 2024 ACC/AHA Guidelines, are used to evaluate baseline myocardial damage and cardiac functional reserve. Detection of eGFR and urinary microalbumin is performed to assess renal function, and blood glucose and glycated hemoglobin levels are measured to clarify diabetes control status, providing a reference for medication adjustment. Cardiac imaging examinations, including echocardiography and coronary angiography, are adopted: echocardiography detects LVEF and wall motion to evaluate myocardial reserve, while coronary CTA and angiography assess disease severity and surgical risks. Comprehensive frailty assessment is conducted for elderly patients to identify high-risk individuals and formulate early intervention plans.

Drug pretreatment is implemented in accordance with guideline-based individualized medication. Intensive statin pretreatment serves as the core measure; high-dose statins are administered 12-24 hours preoperatively to reduce the risk of ischemia-reperfusion injury. Antiplatelet regimens are adjusted individually to avoid bleeding risks. Preoperative administration of nicorandil or Tongxinluo is applied to improve microvascular function for early microcirculation protection. Standardized hydration therapy is the main measure for renal protection to reduce toxic damage caused by contrast agents. Scientific risk stratification and clinical decision-making are carried out based on preoperative screening results: elective PCI is routinely performed for low-risk patients, while multidisciplinary consultation is organized for high-risk patients, and intra-aortic balloon pump implantation or staged interventional therapy is adopted for patients with poor surgical tolerance.

3.2 Intraoperative Stage: Standardized Operation, Microcirculation Protection, and Real-time Monitoring

Standardized operation is the core principle of surgery. Operators shall perform delicate and accurate operations to minimize mechanical damage to vascular endothelium. Targeted pretreatment measures are selected according to different types of vascular lesions to reduce intraoperative risks. Simplified stent implantation principles are followed to avoid unnecessary operations and reduce vascular wall irritation. Once intraoperative complications such as no-reflow occur, intracoronary targeted drugs shall be administered immediately to reverse abnormal hemodynamic status.

Continuous monitoring of vital signs and hemodynamic indicators is maintained intraoperatively, and systolic blood pressure is kept above 90 mmHg. Contrast agent dosage is strictly calculated and controlled, and postoperative hydration therapy is initiated promptly to accelerate contrast agent excretion and protect renal function [7]. Systematic evaluation of coronary microcirculation function is conducted to early identify occult no-reflow cases with unobstructed large coronary arteries but unrecovered microcirculation perfusion, so as to deliver timely and effective intervention.

3.3 Postoperative Stage: Intensive Monitoring, Drug Maintenance, and Complication Prevention

The first 72 hours after surgery are the high-incidence period of perioperative myocardial injury and related complications, so a rigorous monitoring protocol must be formulated. Myocardial injury biomarkers, including high-sensitivity cardiac troponin, are detected at fixed time points of 6 h, 12 h, 24 h, and 48 h after surgery; patients with levels exceeding 5 times the upper limit of the normal range are diagnosed with perioperative myocardial injury and receive intensive treatment [8]. Cardiac function is monitored combined with NT-proBNP detection and echocardiography, and re-examination of cardiac ultrasound is performed 24-48 hours postoperatively to observe changes in LVEF and wall motion. Serum creatinine and eGFR levels are dynamically monitored at 24 h, 48 h, and 72 h after surgery for early warning of contrast-induced nephropathy, and therapeutic regimens are adjusted in a timely manner once renal function declines. Continuous electrocardiographic monitoring is maintained for 48 hours postoperatively to detect and treat malignant arrhythmias at an early stage.

Postoperative medication strategies combine short-term intervention and long-term secondary prevention to optimize therapeutic schemes. Standard dual antiplatelet therapy is adopted: long-term oral aspirin 100 mg once daily, and ticagrelor 60 mg twice daily for 12 months, which can be shortened to 6 months for high-risk patients. High-intensity statins are maintained long-term, including atorvastatin 40 mg or rosuvastatin 20 mg once daily. Microcirculation protective drugs, such as nicorandil 5 mg three times daily and conventional-dose Tongxinluo, are administered for 3 to 6 months. Preoperative hydration therapy is continued for 12-24 hours postoperatively, and dialysis is supplemented for patients with severe renal insufficiency.

A systematic postoperative protection system is established for precise prevention and control of postoperative complications. Targeted interventions are delivered for residual no-reflow to stabilize blood pressure, and vasoactive drugs are supplemented when necessary to improve circulation. Anticoagulant dosage is adjusted individually to prevent bleeding complications; intraoperative heparin dosage is optimized for elderly and low-weight patients to maintain activated clotting time within 250-300 seconds. Close observation and nursing of puncture sites are strengthened to prevent bleeding and hematoma. For postoperative heart failure prevention and treatment, daily infusion volume is strictly controlled within 1000 ml; diuretics such as furosemide are used to reduce cardiac load once symptoms occur, and positive inotropic drugs are combined if necessary to enhance myocardial contractility and stabilize circulation.

3.4 Whole-course Management: Multidisciplinary Collaboration and Individualized Rehabilitation

The prevention and control of perioperative myocardial injury cannot be limited to short-term perioperative intervention, and a whole-cycle management mechanism should be established relying on multidisciplinary collaboration and comprehensive geriatric assessment. A multidisciplinary team covering cardiology, cardiac surgery, nephrology, geriatrics, and rehabilitation medicine is set up. For super-elderly patients aged ≥85 years and those with severe multivessel complex coronary lesions, the team makes unified decisions on preoperative regimen formulation, intraoperative risk control, postoperative complication management, and long-term rehabilitation planning, comprehensively considering combined diseases such as cardiac and renal dysfunction as well as geriatric frailty, so as to avoid limitations of single-discipline diagnosis and treatment.

Regular comprehensive geriatric assessment is carried out to fully evaluate patients' cognitive function, nutritional status, medication compliance, and mental state, identify multiple medication-related risk factors, adjust unnecessary drugs in a timely manner to avoid drug interactions, and correct malnutrition and cognitive disorders to improve treatment tolerance and rehabilitation capacity [9]. Postoperative cardiac rehabilitation adopts hierarchical and individualized modes: mild passive and active in-bed activities are initiated 24-48 hours after surgery to prevent blood stasis and physical function decline caused by prolonged bed rest; walking and aerobic exercise intensity are gradually increased within 1 to 2 weeks after surgery to improve myocardial reserve and physical endurance. Long-term lifestyle intervention is also strengthened to standardize blood pressure, blood glucose, and blood lipid control, advocate smoking cessation and alcohol restriction, and develop a low-salt and low-fat diet, so as to delay coronary lesion progression and reduce the recurrence risk of long-term myocardial injury and cardiovascular events.

4. Basis of Guidelines and Consensus

Domestic and foreign clinical guidelines and expert consensuses provide authoritative evidence-based references for risk factor identification, mechanism clarification, and prevention strategy formulation of perioperative myocardial injury. The 2025 Guidelines for Percutaneous Coronary Intervention recommend the application of intensive statins, Tongxinluo, and nicorandil in perioperative microcirculation protection of coronary interventional therapy, confirming the vital role of anti-inflammatory, antioxidant, and microvascular intervention in preventing myocardial injury, and standardizing preoperative pretreatment, intraoperative emergency treatment, and long-term postoperative maintenance medication.

The 2024 Expert Consensus on Perioperative Cardiovascular Risk Management in Elderly Patients with Coronary Heart Disease emphasizes the necessity of preoperative screening of myocardial biomarkers, including high-sensitivity cardiac troponin and NT-proBNP, as well as frailty scoring, and proposes individualized adjustment of antiplatelet drug dosage according to age, body weight, and renal function to balance ischemic and bleeding risks, providing clear guidance for risk stratification and individualized medication in elderly patients.

The 2025 Chinese Expert Consensus on Microcirculation Protection Strategies for Emergency PCI in Patients with ST-segment Elevation Myocardial Infarction standardizes the diagnosis and treatment protocols for postoperative no-reflow and slow flow, and clarifies the administration timing and dosage of intracoronary sodium nitroprusside and tirofiban. Its intervention approaches for microcirculation disorders are highly consistent with the intraoperative prevention requirements of perioperative myocardial injury in elderly patients with complex coronary lesions, providing authoritative clinical guidance for intraoperative microcirculation protection and emergency management. Evidence-based recommendations from various guidelines and consensus standardize and rationalize the prevention and control strategies for perioperative myocardial injury, which can well meet the clinical treatment needs of elderly patients with complex coronary artery lesions, effectively reduce the incidence of perioperative myocardial injury, and optimize long-term clinical prognosis.

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