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Consensus

Expert consensus on perioperative management for liver tumors treated with co-ablation system therapy

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ABSTRACT

Co-ablation system therapy is currently in its early stages of application in tumor treatment in China. The associated protocols for perioperative management are not yet well-developed and suffer from a lack of corresponding guidelines or consensus. This study aims to improve the quality of clinical treatment and nursing care and to standardize perioperative management for patients with liver tumors undergoing co-ablation system therapy. The Committee of Ablation Therapy in Oncology, China Anti-Cancer Association, and the Committee of Interventional Perioperative, Interventional Physician Branch of the Chinese Medical Doctor Association organized medical and nursing experts in China. Based on the clinical practice of co-ablation system therapy in China and the relevant domestic literature, an expert consensus regarding perioperative management was developed. The expert consensus includes the key points of perioperative management, prevention and care of complications, discharge guidance, and follow-up management for patients who have undergone co-ablation system therapy of liver tumors. The consensus on the perioperative management of co-ablation system therapy for liver tumors has finally been formulated, providing a reference and application for medical personnel in relevant fields based on hospital and patient conditions in clinical work.

Introduction

Primary liver cancer is currently the fifth most common malignant tumor and the second leading cause of cancer-related deaths in China, posing a serious threat to the lives and health of the Chinese population.[1,2] In recent years, the incidence of metastatic liver cancer has shown a significant upward trend, with its rate now far exceeding that of primary liver cancer.[3] Most patients with liver tumors are diagnosed at a stage at which surgical resection or liver transplantation is no longer feasible. Consequently, local ablation, trans-arterial chemoembolization, hepatic arterial infusion chemotherapy, radiotherapy, targeted therapy, and immunotherapy have become crucial therapeutic options in clinical practice.[4]

Local ablation techniques, including radiofrequency ablation, microwave ablation, laser ablation, irreversible electroporation, chemical ablation, high-intensity focused ultrasound (HIFU) ablation, and cryoablation, offer various benefits. Compared with radiofrequency or microwave ablation, cryoablation not only effectively destroys tumors locally but also has advantages such as clearer ablation margins and better activation of immune responses. However, traditional cryoablation carries a high risk of needle tract bleeding and tumor cell seeding and metastasis.[5] The co-ablation system, a composite thermal ablation technology independently developed in China, uses liquid nitrogen and ethanol as the primary agents for heat transfer. This advanced minimally invasive medical system combines deep low-temperature cryotherapy

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with rapid rewarming capabilities, allowing temperature control from −196°C to 80°C. The system initially employs cryotherapy to kill targeted tumor cells at low temperatures, confining them within a specific tissue area and reducing the likelihood of tumor cells spreading along blood vessels. Subsequently, rapid rewarming induces controlled cycles of cooling, freezing, and rewarming, leading to tumor tissue necrosis and effective therapeutic outcomes. During cryoablation, an ablation needle is inserted into the tumor tissue. Liquid nitrogen rapidly flows through the needle, evaporates, and absorbs heat, thereby delivering a substantial amount of cold energy to the tumor tissue instantly and freezing and destroying it. When the system transitions from cryotherapy to rewarming, high-temperature steam is directed through the ablation needle, rapidly releasing a large amount of heat. This causes the needle tip to rewarm quickly and melt the frozen tissue surrounding the needle. This process facilitates needle extraction, ablation of the needle tract, hemostasis, and prevention of tumor seeding along the needle tract.[6]

This technology is currently in the initial stages of application in tumor treatment in China. The associated protocols for perioperative management are not yet well-developed and suffer from a lack of corresponding guidelines or consensus, which makes it difficult for patients to obtain unified and standardized management, thereby affecting treatment effectiveness and quality of life. Therefore, the establishment of a standardized consensus regarding perioperative management for co-ablation system therapy is essential. To this end, the Committee of Ablation Therapy in Oncology, China Anti-Cancer Association, and the Committee of Interventional Perioperative, Interventional Physician Branch of the Chinese Medical Doctor Association jointly organized domestic medical and nursing experts in related fields. In view of current clinical practice and similar domestic literature and guidelines, a consensus on the perioperative management of co-ablation system therapy for liver tumors has finally been formulated, providing a reference and application for medical personnel in relevant fields based on hospital and patient conditions in clinical work.

The members of this consensus expert group conducted literature searches, summarized and organized evidence, evaluated the feasibility, suitability, clinical significance, and effectiveness of the evidence, and proposed suggestions for revision. If no relevant evidence was available to support a certain topic, the expert group would discuss it, provide corresponding suggestions, form a consensus draft, and subsequently conduct an expert inquiry. The inquiry process included evaluating the feasibility and importance of the evidence and proposing suggestions for revision. Finally, this consensus was jointly reached through research and discussion involving more than 30 experts from multiple centers across the country.

Expert consensus guidelines

Preoperative management

Preoperative examinations

(1) Laboratory tests: These include complete blood count, routine urine and stool tests, coagulation function tests, liver and kidney function tests, electrolytes, tumor markers (such as alpha-fetoprotein and abnormal prothrombin), hepatitis B virus (HBV) deoxyribonucleic acid (DNA) titer measurement, preoperative screening for infectious diseases, and blood typing.[7]
(2) Auxiliary examinations: These include chest radiography, electrocardiography (ECG), relevant ultrasonography, and endoscopic examinations to assess cardiopulmonary function comprehensively.
(3) Imaging examinations: These include contrast-enhanced magnetic resonance imaging (MRI) or computed tomography (CT) of the liver within two weeks before ablation.[7] These tests are conducted to determine the size, shape, internal structure, and location of the lesions, as well as their relationship with adjacent vital organs, blood vessels, portal veins, or bile ducts.

Specialized assessment

(1) Systematic assessment: Collect basic patient information including age, disease status, treatment plan, and history of allergies. Document the history of disease progression and treatment, including abdominal surgery, gastrointestinal bleeding, radiotherapy, chemotherapy, and medication history (e.g., anticoagulants, targeted drugs, immunotherapy).[8] Assess the understanding of the patient regarding co-ablation system therapy and their psychological state.
(2) Nursing risk assessment: Conduct comprehensive preoperative assessments including nutritional risk screening, thrombus risk factor evaluation, pain assessment, fall risk assessment, evaluation of self-care ability, and pressure injury risk assessment.
(3) Bleeding tendency assessment: Monitor for signs of bleeding such as skin purpura, ecchymosis, mucosal bleeding, and gum bleeding. Track coagulation function tests, including platelet distribution, fibrinogen, platelet count, and prothrombin time, with special attention paid to uncorrectable coagulation disorders (platelet count $< 60 \times 10^9$/L, prothrombin time $>$ 3 seconds).[1]
(4) Assessment of abdominal symptoms and signs: Evaluate the patient for symptoms such as abdominal pain, distension, and swelling. Physical examination findings such as abdominal swelling, abdominal wall varices, and positive shifting dullness indicate the accumulation of intra-abdominal fluid.[9]

Preoperative preparation

(1) Health education: Explain the purpose of co-ablation system therapy, surgical procedures, related precautions, potential postoperative adverse reactions, and coping strategies to the patient.
(2) Patient preparation: Choose the method of anesthesia based on the condition and treatment needs of the patient. For patients receiving local anesthesia, restrict food and drink for two hours.[10] For patients receiving general anesthesia, restrict food for eight hours and drink for four hours.[1] Establish intravenous access. Conduct breathing exercises and train the patient to perform deep breathing exercises hold their breath for 15–20 seconds after each deep breath. Each breath should maintain a consistent depth to minimize the impact of respiratory movements during surgery.
(3) Management of underlying diseases: Ensure that antiplatelet aggregation and blood-activating and stasis-resolving drugs are discontinued one week before surgery. Administer appropriate medications based on bleeding tendency assessments to improve coagulation function. Intensify blood pressure monitoring in hypertensive patients and blood glucose monitoring in diabetic patients.[8]
(4) Management of susceptible populations: Elderly patients and those with poor overall nutritional status, long-term use of chemotherapy drugs or steroids, history of biliary stent placement or surgery causing sphincter of Oddi dysfunction, or high-risk conditions such as severe diabetes, liver cirrhosis, or cholelithiasis have an increased risk of infection or formation of a severe liver abscess during or after ablation. Therefore, ensure that preoperative bowel preparation is performed as per medical advice (e.g., administering cleansing enemas or oral antibiotics to prevent infection).[8]

Psychological care

Preoperative psychological care can effectively alleviate the negative emotions of patients and improve compliance. Techniques such as motivational belief interventions combined with psychological counseling can improve the psychological state, sleep quality, and coping mechanisms of patients undergoing liver cancer ablation.[11] Individualized and multimodal approaches can also be employed. For example, using educational brochures, multimedia videos, or animations can help

patients fully understand the surgical procedure and its significance, thereby reducing their anxiety and increasing knowledge.[12] This clarity can help patients recognize their role in the treatment process and enhance their psychological safety.

Intraoperative management

Preparation of surgical environment and personnel

(1) Surgical environment: Co-ablation system therapy for liver cancer is performed in a CT or ultrasound operating room. The operating room must comply with the "Technical Specifications for Clean Operating Department in Hospitals" (GB50333-2013), meeting the Class III standard for clean operating rooms.[13]
(2) Environmental conditions: According to the "Technical Specifications for Clean Operating Department in Hospitals" (GB50333-2013), the operating room temperature should be maintained at 21–25°C, with a humidity level between 30% and 60%. A heating blanket with a constant temperature of 37°C should be prepared on the operating table.[14]
(3) Sterile techniques: Adhere to surgical aseptic principles including the use of maximal sterile barriers such as caps, surgical masks, sterile gloves, and sterile surgical gowns. In addition, use sterile drapes to cover the entire patient.

Preparation of items

(1) Equipment preparation: Prepare the co-ablation system, ECG monitor, and anesthesia pump, and check whether all equipment is in good working order.
(2) Consumables and medications: Prepare single-use sterile cryoablation needles, anesthetics, analgesics, and routine emergency drugs.
(3) Emergency supplies: Prepare emergency carts, central oxygen, suction machines, and manual resuscitator bags.

Patient preparation

(1) Verification: Verify the basic information of the patient and the surgical site. Comprehensively assess the history of hypertension, heart disease, diabetes, allergies, and use of anticoagulant medications.
(2) Positioning: Choose the appropriate surgical position based on tumor size and location. Assist in positioning the patient on the examination bed, using positioning pads as necessary. Raise the right arm or both arms above the head if necessary to expose the surgical area fully, while protecting the privacy of the patient and providing adequate warmth.

Intraoperative operation and observation

(1) Patient guidance: Instruct the patient to cooperate with the medical team, provide continuous ECG monitoring, and maintain a low-flow oxygen supply. Ensure that the intravenous line remains patent and direct the patient to maintain the surgical position and signal any discomfort or need to the medical staff.
(2) Surgical assistance: Assist the surgeon with sterilization and with the draping of sterile surgical towels and administration of anesthesia. Prepare the required surgical instruments, medications, and single-use sterile items.
(3) Equipment check: Assist the surgeon in checking the co-ablation system equipment. The specific steps include opening the liquid nitrogen channel, testing the needle tip freezing in the air, and opening the alcohol channel for thawing to check for air leaks and proper functioning of the cryoprobe. Ensure that the parameters match the preset values.
(4) Cryoablation procedure: Assist the surgeon in accurately inserting the co-ablation system needle into the tumor tissue. Follow the set protocol for co-ablation system therapy: freeze at the target temperature of −196°C for 10–15 minutes, then thaw to a maximum of 80°C for 3–5 minutes. One freeze–thaw cycle consists of one freezing and one thawing phase. Repeat 2–3 cycles based on the tumor conditions. Record the freezing and thawing time and temperature.
(5) Monitoring and prevention of complications: Closely monitor the vital signs of the patient to check for any indications of intraoperative bleeding, pain, skin frostbite, or cold shock. Focus on preventing skin frostbite by ensuring adequate blood perfusion and minimizing the drops in temperature. Increase the operating room temperature and use a heating blanket with a constant temperature of 37°C. For skin protection after successful puncture, apply sterile gauze soaked in 75% alcohol around the puncture site to keep it moist.[15,16] Alternatively, use sterile warm water bags made from sterile gloves filled with warm sterile saline and press them against the skin around the puncture site to ensure better heat transfer and local skin protection.[17]
(6) Patient care: Provide humane care throughout the surgery by offering comfort, reassurance, and encouragement to stabilize the emotions of the patient.

Postoperative management

Transfer and handover

(1) Transfer: Once the vital signs of the patient are stable, the medical staff should use a stretcher to transport the patient safely to the ward.
(2) Handover: Ensure a thorough handover, including details regarding the type of anesthesia, intraoperative vital signs, complications and their management, special medications, condition of the skin and puncture site, and postoperative precautions.

Activity and monitoring

Provide continuous low-flow oxygen. Use a bedside ECG monitor to track changes in vital signs and blood oxygen saturation, adjusting the duration of monitoring based on the condition of the patient. Patients who have received general anesthesia should remain supine without a pillow for six hours and rest for 24 hours postoperatively.

Condition observation

Monitor changes in the level of consciousness of the patient. Check for bleeding or exudates on the puncture site dressing. Observe the skin around the puncture site for symptoms of frostbite such as redness, blisters, or burning pain. Monitor for fever, pain, gastrointestinal reactions, chest tightness, or shortness of breath, and manage symptoms accordingly.

Dietary care

Patients who have received general anesthesia can resume normal eating after six hours postoperatively, whereas those who have received local anesthesia can do so after two hours postoperatively.[10] Patients may drink warm water and consume a diet that is low in fat and high in protein, carbohydrates, and vitamins, or a semi-liquid diet.[18] Encourage small and frequent meals, and monitor for nausea, vomiting, abdominal pain, or bloating after eating.

Prevention and management of major complications

Post-ablation syndrome

Post-ablation syndrome is one of the most common postoperative complications. Patients typically present with flu-like symptoms including fever, general malaise, chills, and gastrointestinal reactions such as nausea. The most common symptoms are fever and general malaise, whereas chills and nausea occur less frequently.[19] These

symptoms are usually transient and self-limiting and resolve within two weeks;[6] they are caused by the absorption of necrotic tissue and release of inflammatory factors following tumor ablation.[20]

Management

(1) Temperature monitoring: Closely monitor changes in temperature, generally ranging between 37.5°C and 38.5°C.

(2) Comfort maintenance: Ensure good ventilation. Assist patients in changing sweaty clothes and keep their skin dry to promote comfort.

(3) Physical cooling: Provide tepid sponge baths or ice packs to reduce fever.

(4) Pharmacological cooling: Administer antipyretic and analgesic medications as prescribed if the temperature exceeds 38.5°C. Educate patients and their families on the correct usage, dosage, and precautions of these medications.

(5) Laboratory monitoring: For patients with persistent high fever, regularly monitor infection markers to remain vigilant for potential infections.

(6) Dietary care: Guide patients to consume light, easily digestible, and nutrient-rich foods and avoid spicy, greasy, and irritating foods.

(7) Gastrointestinal care: During vomiting, turn the head of the patient to one side to prevent aspiration. Administer antiemetic medications as prescribed if necessary.

Pain

Pain is often most noticeable on the day of surgery and the following day then gradually subsides over the subsequent 1–3 days. It is associated with surgical trauma, local swelling caused by tumor tissue ischemia and necrosis, the release of pain-inducing inflammatory mediators, increased liver capsule tension, and irritation of the liver capsule by puncture needles.[21–23] Pain can be controlled using appropriate analgesic medications.

Management

(1) Pain assessment: Conduct a comprehensive assessment of the nature, location, intensity, and cause of the pain. Use tools such as the Numeric Rating Scale (NRS) or Faces Pain Scale (FPS) to evaluate pain levels.[22]

(2) Mild pain relief: Assist patients in finding a comfortable position, help distract them from the pain, and teach them relaxation techniques such as slow breathing and listening to music.

(3) Moderate-to-severe pain relief: Administer analgesic medications as prescribed, educate patients and their families about the medications, and monitor analgesic efficacy and adverse reactions.

(4) Psychological care: Pay attention to the psychological changes of the patient, provide them with comfort and positive encouragement, and help them maintain a good psychological state to indirectly alleviate any discomfort caused by pain.[24]

Bleeding

Bleeding is one of the most severe complications of combined cryoablation and thermal ablation therapy for liver tumors and can potentially result in patient death.

Intrahepatic bleeding

This complication includes subcapsular liver hemorrhage, liver rupture, and bile duct bleeding, usually occurring within 48 hours postoperatively. Potential causes include significant differences in temperature between the inside and outside of the ice ball during cryoablation leading to ice ball rupture and subsequent vascular or tumor rupture,[21] cryoablation-induced liver damage causing thrombocytopenia or coagulation factor consumption resulting in coagulation disorders,[25] bleeding from the ablation needle tract, and puncture damage to the intrahepatic bile ducts.

Management

(1) Preoperative bleeding tendency assessment: As detailed in the preceding section of this consensus titled “Preoperative management,” correct coagulation issues in patients with poor coagulation function before treatment.

(2) Intraoperative bleeding management: Administer hemostatic drugs as prescribed if bleeding occurs intraoperatively and use the advantages of combined cryoablation and thermal ablation to achieve hemostasis. For severe bleeding, refer to the "Expert Consensus on Emergency Nursing for Life-threatening Massive Hemorrhage (2019)"[26] and intervene promptly based on the urgency and severity of the situation.

(3) Postoperative monitoring: Observe vital signs carefully and monitor the patient closely for any signs of bleeding within 24 hours postoperatively. Monitor changes in blood count, especially platelet count and hemoglobin concentration. Patients with bleeding should remain on strict bed rest and avoid vigorous activity.

(4) Subcapsular liver hemorrhage: Early stages often lack typical clinical manifestations and are mostly self-limiting. If the bleeding volume is significant, symptoms such as progressive abdominal pain, decreased blood pressure, increased heart rate, irritability, or shock may occur. Immediate postoperative enhanced CT scans can detect most hemorrhages; an increase in contrast extravasation indicates active arterial bleeding.[27] Early preparation for arterial embolization should be performed as prescribed if active arterial bleeding is detected.[28,29]

(5) Liver rupture: This complication presents with sudden severe pain in the liver area and may be accompanied by shock if the bleeding volume is large. Bleeding should be actively stoppedand symptomatic treatment should be provided upon diagnosis, including blood transfusion and anti-shock treatment if necessary. Prepare for embolization or surgical hemostasis if conservative medical treatment is ineffective.

(6) Bile duct bleeding: This issue results from surgical damage to the intrahepatic bile ducts and their accompanying hepatic artery or portal vein branches, resulting in blood entering the bile duct system. Manifestations include hematemesis and melena. Observe the frequency, amount, color, and nature of the hematemesis and melena carefully, and turn the head of the patient to one side during hematemesis to prevent asphyxiation.

Upper gastrointestinal bleeding

This rare complication is primarily caused by the rupture of esophagogastric varices, acute gastric mucosal bleeding, or stress ulcer bleeding.[1]

Management

(1) Patients with portal hypertension and esophagogastric varices: Administer gastric mucosal protectants as prescribed before and

after surgery. Instruct patients to consume soft foods and avoid excessively hot foods, and prohibit the consumption of hard foods such as nuts.

(2) Close observation: Monitor the conditions closely. Severe vomiting should be controlled promptly to avoid the rupture of esophagogastric varices.

(3) Bleeding management: Follow the principles for handling bleeding secondary to the rupture of esophagogastric varices.[30]

Infection

Infection of the ablation zone is often secondary to liquefactive necrosis of the ablated tissue or biliary infection. If bile accumulates owing to bile duct injury, it can develop into a liver abscess.[1] The primary manifestations include irregular chills, high fever, and elevated total white blood cell and neutrophil counts or proportions.

Management

(1) Management of preoperative susceptible populations: Refer to the preceding section of this consensus titled "Preoperative management."

(2) Postoperative monitoring: Closely monitor changes in temperature and track infection markers in a dynamic manner. If unexplained chills or high fever (especially if accompanied by chills) occur within 3–5 days postoperatively, infection should be strongly suspected and promptly reported to the physician for timely diagnosis.

(3) Early antibiotic use: Administer antibiotics early and as prescribed.

(4) Bed rest and hydration: Advise patients to rest in bed. Patients with excessive sweating or persistent high fever should be encouraged to increase their fluid intake to prevent excessive fluid loss and maintain fluid balance; however, this should be done according to the instructions of the physician and under close supervision to prevent electrolyte imbalances.

(5) Liver abscess: Ultrasonography and CT scans can confirm the diagnosis. For larger abscesses, physicians should be assisted in liver puncture and drainage tubes should be placed for drainage of pus. Conduct bacterial cultures and sensitivity tests on the pus to guide the targeted use of antibiotics. Maintaining the patency of drainage tubes is crucial for treatment; tube dislodgement, kinking, compression, twisting, and blockage should be avoided. If the pus is thick and drainage is poor, flush the pus cavity while strictly adhering to aseptic techniques. Observe and document changes in the nature, color, and amount of pus.

(6) Monitoring for signs of septic shock: Observe changes in the level of consciousness, vital signs, skin, and urine output of the patient to remain vigilant for the occurrence of septic shock.

Liver function damage

Co-ablation system therapy can cause necrosis of the tumor and surrounding liver tissue, leading to an increased liver burden owing to the absorption of necrotic tissue. The extensive freezing range can cause hepatocellular jaundice and ascites in patients with poor liver function. The treatment involves hepatoprotective, antijaundice, and diuretic therapies.[31]

Management

(1) Postoperative patients should avoid early mobilization and instead should primarily rest in bed for 3–5 days and maintain adequate sleep.

(2) Encourage patients to consume a high-calorie, high-vitamin, and easily digestible diet.

(3) Observe for jaundice in the skin and sclera, and regularly monitor liver function tests and electrolytes.

(4) Monitor for abdominal distension, abdominal pain, and lower limb edema. Record 24-h urine output.

(5) For patients with ascites, measure abdominal circumference regularly, monitor ascites closely, and administer diuretics as prescribed.

(6) Maintain smooth bowel movements. If no bowel movement occurs within three days postoperatively, administer oral lactulose or retention enemas with lactulose or glycerin suppositories to prevent elevated blood ammonia levels.[18,32,33]

Thrombocytopenia

Co-ablation system therapy can cause thrombocytopenia secondary to hepatocyte damage, resulting in reduced secretion of thrombopoietin and decreased platelet production. In addition, systemic inflammatory responses or platelet aggregation and sequestration in frozen areas can lead to thrombocytopenia. This may also be related to the direct activation of platelet apoptotic proteases by inflammatory cytokines released after freezing, which causes platelet fragmentation and reduction.[34]

Management

(1) When the platelet count is $< 50 \times 10^9$/L, enforce strict bed rest to avoid strenuous activity.

(2) Extend the compression time at puncture sites during invasive procedures.

(3) Closely monitor changes in the skin and mucous membranes, especially noting and recording the presence of ecchymosis and petechiae, and assess for gingival bleeding. If a tendency for bleeding is present, interventions such as local compression hemostasis should be implemented promptly.

(4) Carefully observe the color and characteristics of the urine and stool of the patient, as well as abdominal symptoms and signs, to detect signs of gastrointestinal and internal organ bleeding.

(5) Remain vigilant for the risk of intracranial hemorrhage. Monitor vital signs and observe changes in consciousness, pupils, and limb strength.

(6) Closely monitor changes in blood count. According to the "Expert Consensus on the Emergency Management of Adult Thrombocytopenia in China,"[35] platelet transfusion may be indicated in cases of acute thrombocytopenia (platelet count $< 10 \times 10^9$/L) with a tendency for bleeding, and strict adherence to platelet transfusion protocols and management is essential.

Renal function injury

Extensive freezing during ablation can release large amounts of liquefied metabolic products into the bloodstream, leading to diffuse precipitation in the renal pelvis and causing renal obstruction and damage to renal function, with severe cases potentially resulting in acute renal failure. Some patients may develop dark-colored urine 1–3 days postoperatively.[8]

Management

(1) Encourage patients to drink plenty of water to expedite the excretion of metabolic products and reduce renal damage. Administer 5% sodium bicarbonate intravenously to alkalinize the urine and provide adequate hydration and diuretic treatment as prescribed.

(2) Closely monitor urine output and color within 1–3 days postoperatively, ensuring that 24-h urine volume remains above 2000 mL. If the patient develops dark-colored urine or urine output $<$ 30 mL/h, notify the physician immediately for appropriate diuretic and renal function assessment.

(3) Regularly re-evaluate renal function, urinalysis, and electrolytes to understand the renal function status promptly.

Frostbite

Frostbite primarily occurs during the cryoablation of tumors near the liver capsule, particularly with multiple-needle cryoablation, in which care should be taken to avoid close spacing between the needle insertion points.[1] Frostbite severity is classified into four grades: first-degree (erythematous frostbite), second-degree (blistering frostbite), third-degree (eschar frostbite), and fourth-degree (gangrenous frostbite).[36] Post-cryoablation skin frostbite is mostly first- and second-degree and manifests as erythema, blisters, and burning pain.

Management

(1) Closely observe local skin color, temperature, exudation, and blister formation postoperatively.

(2) Small blisters do not require special treatment; keep the wound dry and they will resolve spontaneously within a few days.

(3) For larger blisters, aspirate the fluid using a sterile syringe and apply a frostbite ointment to the wound to ensure skin integrity.

(4) For significant erythema, apply magnesium sulfate wet compresses while avoiding blisters and ulcerated areas.[8]

(5) In cases of third-degree or higher frostbite, promptly consult a dermatologist or wound care specialist for appropriate treatment.

Cryoshock

Cryoshock refers to multi-organ dysfunction following cryoablation, which can lead to severe clinical syndromes such as disseminated intravascular coagulation (DIC). Symptoms include chills, low limb temperature, rapid and weak pulse, hypotension, and dyspnea. Although rare, cryoshock is the most severe complication of cryoablation. The mechanism is unclear but may involve activation of nuclear factor-κB (NF-κB) and increased release of NF-κB-dependent cytokines after freezing, as well as the involvement of inflammatory factors produced by hepatic macrophages secondary to liver injury. Prevention is crucial and should focus on maintaining warmth during and after surgery.[8]

Management

(1) Ensure that intravenous access is maintained to support tissue perfusion.

(2) Maintain room temperature above 25°C and use a heated blanket with a temperature of 37°C during surgery.

(3) Encourage patients to drink warm water postoperatively.

(4) Closely monitor vital signs, provide continuous low-flow oxygen if necessary, and observe peripheral circulation in the extremities.[8,14]

Thoracic complications

Thoracic complications frequently occur during the treatment of tumors at the top of the diaphragm. Owing to the high tumor position, ablation needles may penetrate the diaphragm into the thoracic cavity or adhere closely to the diaphragm, causing injury to the diaphragm or lung and leading to pulmonary infection, pneumothorax, and reactive pleural effusion.[37] The ablation needle may also directly damage intrapulmonary vessels or intercostal arteries, thereby resulting in hemothorax.

Management

(1) Closely observe the respiratory status of the patient in the postoperative period, noting breathing rhythm, rate, bilateral lung sounds, and symptoms such as dyspnea, chest tightness, and shortness of breath.

(2) Closely monitor vital signs and administer oxygen based on blood oxygen saturation.

(3) For small pneumothorax and pleural effusion, conservative management is generally sufficient, as these complications often undergo spontaneous absorption within approximately one week. In cases of moderate to large pneumothorax or pleural effusion, thoracentesis or closed thoracic drainage is recommended.[6]

(4) For patients with closed thoracic drainage, follow the requirements of the group standard of the Chinese Nursing Association (T/CNAS 25—2023)[38] for chest tube care, and guide patients in early pulmonary function exercises.

Hollow organ injury

Tumors near or directly adhering to hollow organs such as the bile ducts, gallbladder, and gastrointestinal tract may be damaged during ablation and consequently experience rupture or perforation. This can lead to internal or external leakage of bile or intestinal fluid, resulting in chemical or bacterial peritonitis and, in severe cases, infectious shock or even death.[1]

Management

(1) For patients with tumors near the gastrointestinal tract or a history of abdominal surgery, prepare the gastrointestinal tract preoperatively as prescribed, such as with enemas or gastric tube placement.

(2) Intraoperatively, use artificial ascites techniques to isolate and protect adjacent organs as needed.

(3) Closely observe the patient postoperatively for abdominal symptoms and signs such as abdominal tenderness, rebound tenderness, muscle tension, and severe abdominal pain or distension. Observe the characteristics of any fever (chills and high fever) and ensure prompt identification and intervention.

(4) Monitor indicators of infection and assist with ultrasonography or CT scans as needed for diagnosis.

(5) For gastrointestinal injury, follow medical advice for fasting, gastric decompression, ensuring smooth drainage, and enhancing parenteral nutritional support.

(6) For bile leaks, perform puncture drainage, maintain the drainage tube, and observe the nature and amount of the drained fluid.

(7) Prepare for emergency exploratory laparotomy if necessary.

Diaphragmatic injury

Co-ablation system therapy for tumors near the diaphragm may cause varying degrees of diaphragmatic injury. Mild cases may present with pleural effusion, which can improve with drainage and anti-infection treatments. Severe cases may result in diaphragmatic perforation, diaphragmatic hernia, diaphragmatic bleeding, biliothoracic fistula, and biliobronchial fistula; such cases present with chest tightness, cough, yellow purulent sputum, abdominal pain, abdominal distension, and signs of intra-abdominal hemorrhage, and they require surgical treatment.[39,40]

Management

(1) Follow aseptic techniques strictly to prevent and control pulmonary infections.

(2) Maintain airway patency.

(3) For patients with indwelling tubes, proper drainage care should be provided.

(4) Encourage patients to engage in moderate activity and lung function exercises to prevent atelectasis.

(5) Closely monitor changes in the condition of the patient, observe vital signs, and promptly identify complications and intervene as needed.[41,42]

Discharge instructions

Dietary guidance

Maintain a varied diet with a focus on high-protein, high-carbohydrate, high-vitamin, and easily digestible foods (fish, lean meat, poultry, and eggs). Avoid spicy, irritating, and high-fat foods. Eat small and frequent meals, and consume plenty of fresh vegetables and fruits.

Medication guidance

Instruct patients about the correct use of antiviral and hepatoprotective drugs and teach them how to observe adverse drug reactions. Conduct regular blood tests and advise patients to seek follow-up care if they experience discomfort or abnormal blood results.

Lifestyle guidance

Advise patients to rest primarily for the first postoperative week and to avoid strenuous exercise and heavy physical activity. Promote a balanced routine of rest and activity, incorporating light exercises such as walking, Tai Chi, and Ba Duan Jin. Ensure adequate sleep and maintain regular bowel movements. Advise patients to avoid smoking and alcohol consumption.

Psychological guidance

Encourage patients to maintain a positive mindset and teach them self-care and self-regulation techniques. Help them face their illness positively and build confidence in overcoming it.

Continuation of care

(1) After complete ablation, regular follow-up and reexamination should be conducted. Generally, ultrasound, MRI, or CT, and tumor markers (such as alpha-fetoprotein and abnormal prothrombin) should be reexamined every 2–3 months to detect possible local recurrent lesions and new liver lesions in a timely manner. After one year, the follow-up interval can be extended by 3–6 months.[1]

(2) Use the telephone or WeChat for regular follow-ups to reinforce patient guidance on self-care at home. Adverse reactions should be promptly identified and managed, and early detection and treatment should be ensured. Remind patients to attend scheduled follow-up appointments.

Conclusions

The objective of this consensus is to promote the standardized domestic management of combined thermal and co-ablation system therapy for the treatment of liver tumors, increase the safety of patients receiving treatment with this technology, reduce the occurrence of related complications, and ensure medical safety. Medical personnel should fully realize the importance of standardized perioperative management for the application of compound thermal and co-ablation system therapy, grasp the relevant contents and requirements of the consensus, provide patients with scientific and standardized medical and nursing services, ensure treatment effectiveness, and improve the quality of life of patients.

CRediT authorship contribution statement

Jingjing He: Methodology, Conceptualization, Writing – Original draft preparation. **Mengjie Shen**: Methodology, Formal analysis, Writing – Original draft preparation. **Yin Xu**: Methodology, Writing – Reviewing and Editing. **Zhongmin Wang**: Writing – Reviewing and Editing, Supervision. **Weijun Fan**: Writing – Reviewing and Editing, Project administration. **Xin Ye**: Writing – Reviewing and Editing. **Xiuhong Ren**: Writing – Original draft preparation. **Ke Chen**: Writing – Original draft preparation. **Jiangxu Zhang**: Writing – Original draft preparation. All authors had full access to all the data in the study, and the corresponding author had final responsibility for the decision to submit for publication. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Ethics statement

Not required.

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