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Targeting gray rami communicantes, not sympathetic trunk, in selective chemical lumbar sympathectomy --Manuscript Draft--

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TITLE:

Targeting Gray Rami Communicantes in Selective Chemical Lumbar Sympathectomy

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KEYWORDS:

Chemical lumbar sympathectomy, complication, gray rami communicante, minimally invasive, ramicotomy, sympathetic trunk

SUMMARY:

We present a protocol for selective chemical lumbar sympathectomy (CLS), which inactivates only gray rami communicantes and not the sympathetic trunk. Selective CLS can help achieve therapeutic efficacy in vasodilation, sweat reduction, and pain relief that are comparable to conventional CLS, and serious complications, particularly ureteropelvic damages, can be reduced.

ABSTRACT:

Chemical lumbar sympathectomy (CLS) is a commonly used, minimally invasive procedure for the treatment of conditions including ischemic diseases of the lower extremities, hyperhidrosis, *etc.* It is commonly practiced to position the puncture needle tip in front of the anterior fascia of the psoas major muscle and inject the inactivating agent around the sympathetic trunk, which is defined as conventional CLS. Although relatively rare, ureteropelvic damage is the most frequently reported complication of conventional CLS and can cause serious harm to patients. We found that injecting the inactivating agent behind the anterior fascia, which only targets gray rami communicantes, helped achieve therapeutic efficacy in measures of vasodilation, sweat reduction, and pain relief comparable to conventional CLS, and serious complications were largely reduced. We define this procedure as selective CLS. Here, we present a protocol of selective CLS. The precise needle tract and accurate evaluation of the spreading of the contrast agent are critical to ensure that the drug is injected behind the anterior fascia of the psoas major

muscle. The needle tip is at approximately one-third the dividing line of the vertebral body in the lateral view of a lumbar X-ray. The contrast is mainly confined around the needle tip and spreads outward and downward along the psoas muscle fibers. In this way, the anterior fascia provides a natural barrier for the ureteropelvic area, and the psoas major muscle provides a natural barrier for the lumbar nerve root. There are several highlights of this article, including 1) a detailed description of the selective CLS procedures, 2) an explanation of the anatomical basis for the implementation of selective CLS, and 3) an explanation of the differences between selective and conventional CLS.

INTRODUCTION:

Chemical lumbar sympathectomy (CLS) has been shown to be an effective treatment for ischemic diseases¹⁻⁵ including thromboangiitis obliterans (sometimes called Buerger's disease), ischemic diabetic foot, Raynaud's disease, palmoplantar hyperhidrosis⁶, erythromelalgia⁷⁻⁹, and livedo reticularis¹⁰. It has replaced open surgery due to a number of advantages. It is minimally invasive and economically attractive, it does not require general anesthesia and hospitalization, and it can be performed repeatedly. However, exquisite precision is critical. For example, paraplegia has been reported in CLS using blind technique¹¹. The precision of the procedure is greatly improved with radiographical guidance to control the exact position of the puncture needle tip and puncture path and depth, through the use of contrast media to visualize treatment areas. However, even with radiographical guidance, damages to adjacent organs, particularly ureteropelvic organs¹²⁻¹⁹, have still been reported.

It is commonly practiced to position the needle tip beyond the anterior fascia of the psoas major muscle and inject the drug around the sympathetic trunk^{8,12-15}, which we define as conventional CLS. However, because the location of the sympathetic trunk and ureter are both in front of the anterior fascia, inactivating agents may spread to the ureter and cause damage. In reports of ureteropelvic damage that presented radiographic images¹²⁻¹⁵, the drug was injected in front of the anterior fascia, according to contrast spreading.

Based on our prior experience performing CLS procedures, we have found that targeting gray rami communicantes is more effective and safe compared to targeting the sympathetic trunk. Gray rami communicantes are postganglionic sympathetic fibers located behind the sympathetic trunk and in front of the lumbar nerve root, running along the lateral edge of the vertebral body, mostly within the psoas major muscle. Thus, the anterior fascia provides a good barrier for the ureteropelvic area, and the psoas major muscle provides a good barrier for the lumbar nerve root. We define this procedure as selective CLS, and the technical details of selective CLS are described in this protocol.

PROTOCOL:

The protocol has been approved by the local medical and ethics committees. The procedure lasts approximately 15 minutes per side.

1. Indications

1.1. Ensure the patient has the following indications for CLS: thromboangiitis obliterans (Buerger's disease), ischemic diabetic foot, Raynaud's disease, parmpoplantar hyperhidrosis, erythromelalgia, phantom limb pain, or livedo reticularis of the lower extremities.

2. Contraindications

2.1. Exclude the patient if any of the following contraindications are fulfilled: spinal deformity, bleeding tendency, any infection in the procedure-involved areas, unstable vital signs, pregnancy, or any conditions that render the ability for compliance with the procedure.

3. Preoperative Preparation

3.1. Confirm the presence of indications and lack of contraindications based on clinical and laboratory results.

3.2. Obtain written, informed consent from the patient/relative.

4. Treatment Procedure

4.1. Patient position: ensure that the patient is in lateral decubitus position with the side to be treated facing upwards and the lower limbs flexed to make the back as stretched as possible.

4.2. Disinfection: disinfect the skin at the planned needle puncture site (approximately 30 cm diameter) with 2% povidone iodine, twice. Then, cover the patient's back with surgical towels.

4.3. Anesthetization of the needle tract under lateral fluoroscopy guidance: anesthetize the skin and entire needle tract with 5-8 mL of 0.5% lidocaine (2% lidocaine diluted in 0.9% saline solution) without vasoconstrictors. Advance the needle under local anesthesia to the vertebral body surface gradually. Position the needle tip in the optimal injection area.

NOTE: The puncture point on the skin is approximately 7-8 cm from the dorsomedial line, depending on body shape. **Figure 1A** shows the needle tract. **Figure 1B** shows the optimal injection area, which is at approximately one-third the dividing line of the vertebral body in the lateral view of a lumbar X-ray.

4.4. Confirmation of the accuracy of the needle position with contrast agent: after ensuring that the needle tip is in the optimal area in the lateral view of a lumbar X-ray, inject 0.5 mL of the contrast agent to further evaluate the correct position of the needle tip.

NOTE: The goal is to keep the contrast agent mainly confined to the optimal area then spreading along the psoas major muscle. Distribution of the contrast along the psoas muscle fibers is the marker of successful injection behind the anterior fascia (**Figure 2**).

4.5. Injection of inactivating agent, 5% phenol: after aspiration, to ensure no puncture accidents, inject 2 mL of 5% aqueous solution of phenol into the optimal area (adjust the needle tip direction to ensure 1 mL of phenol spreads to the direction of the head then 1 mL of phenol to the direction of the foot). Then, withdraw the needle from the skin and compress and cover the puncture site with gauze to achieve hemostasis.

NOTE: Steps 4.3 to 4.5 were performed at L3 and L4, respectively.

4.6. Evaluation of the efficacy of sympathetic interruption: define satisfactory sympathetic interruption as a rise of at least 2 °C in skin temperature 5 min after the completion of step 4.5. If satisfactory interruption is not achieved, perform supplemental injection to another optimal area or L5, with a total phenol volume no larger than 10 mL for both sides. Perform the other side in the same manner if needed. Measure the skin temperature using an infrared thermometer, and calculate the average among temperature increases in the shin, plantar, and dorsal foot.

5. Postoperative Care

5.1. Encourage the patient to drink water and ambulate after completion of the procedure. Check the patient on the following day for any discomfort, especially in the loin, groin, and thigh, and for improvement of symptoms and any signs of primary disease. Measure the skin temperature as described in step 4.6. Follow-up with the patient accordingly.

REPRESENTATIVE RESULTS:

The needle tip should be in the optimal area as shown in **Figure 1**. In selective CLS, the contrast is injected behind the anterior fascia of the psoas major muscle, targeting gray rami communicantes. A comparison of contrast spreading in selective CLS (A) and conventional CLS (B) is shown in **Figure 2**.

The expected clinical effects are vasodilation (for treatment of Raynaud's syndrome, livedo reticularis, thromboangiitis obliterans, ischemic diabetic foot, and erythromelalgia; **Figure 3**), sweat reduction (for treatment of hyperhidrosis), and pain relief (for treatment of erythromelalgia and phantom limb pain).

FIGURE LEGENDS:

Figure 1: Relationship between puncture needle and surrounding organs/tissues. (A) A diagram of an axial lumbar CT scan at the level of the needle tract. The white line represents the needle tract. It should be noted that the needle tip reaches close proximity to, but does not break through, the anterior fascia of the psoas muscle (red arc). A = abdominal aorta, V = inferior vena cava. (B) Lateral view of a lumbar X-ray. The green area illustrates the optimal area, located beside the lumbar vessels (usually located in the middle of the vertebral body horizontally), behind the anterior fascia of the psoas muscle and away from the lumbar nerve root behind the vertebral body. This is a safe location, closest to the gray rami communicantes. A = lumbar artery, V = lumbar vein.

Figure 2: Comparison of contrast agent spreading in X-ray views between selective CLS (A) and conventional CLS (B). (A) Selective CLS. The contrast agent was injected behind the anterior fascia of the psoas muscle. The lateral view showed that the contrast agent spread around and behind the needle tip. The anterior-posterior (AP) view showed that the contrast agent diffused outward and downward along the spaces among psoas muscle fibers and formed thin strips, outlining the contour of the muscle fibers. (B) Conventional CLS. The contrast agent was injected in front of the anterior fascia of the psoas muscle. The lateral view showed that the contrast was concentrated in loose tissue in front of the needle tip. The AP view showed that the contrast agent was concentrated along the vertebral body, thus overlapping with the vertebral body in X ray view, and did not diffuse outward.

Figure 3: Clinical observation after selective CLS on the right side of a patient with erythromelalgia. The patient's blood vessels dilated, skin temperature increased, and skin was rosy and dry on the right limb. In contrast, skin was damp and cold with a slight violaceous skin color on the left side without treatment.

Figure 4: Anatomic illustration of sympathetic trunk and gray rami communicantes. (A) Anatomically, the psoas muscle is attached to the lateral side of the vertebral body and the lumbar disc (LD). In this illustration, most of the anterior fascia of the psoas muscle is removed, exposing the psoas muscle. The lumbar sympathetic trunk, located in front of the anterior fascia and adjacent to the abdominal aorta (right lumbar sympathetic trunk adjacent to inferior vena cava, not shown). The enlarged lumbar sympathetic ganglia (SG) are also visible. (B) With the psoas muscle removed from the outside of the vertebral body, the lumbar blood vessels and gray rami communicantes covered in the deep side of the psoas muscle are exposed. The gray rami communicantes originate from the sympathetic ganglia, extend through the anterior fascia, extend backward along the lateral edge of the vertebral body, surround the lumbar blood vessels, and finally join the lumbar nerve roots.

DISCUSSION:

Here we classify CLS as either conventional or selective CLS, with the major difference being the targeting of sympathetic trunk vs. gray rami communicantes (injection of phenol in front of vs. behind the anterior fascia of the psoas major muscle). We have implemented selective CLS in young, female patients with livedo reticularis¹⁰, children with erythromelalgia^{7, 9}, and senile patients with end-stage arteriosclerosis obliterans and high-risk comorbidities, and we have confirmed its long-lasting, beneficial effects and safety.

Ureteropelvic damage is the most frequently reported complication of CLS. There have been more than 10 cases reported¹²⁻¹⁹. In one report, the incidence was reported as 1.24% (3 fibrotic ureter stenoses out of 241 CT-guided CLS)¹⁶, and the author concluded that damage to the ureter may follow even when the procedure is technically satisfactory. Although relatively rare, this complication is serious and causes great harm to the patient. In selective CLS, anterior fascia can provide a natural protective barrier of important organs such as the ureter, abdominal aorta, and inferior vena cava. In our hospital, ureteropelvic damage has never occurred in more than 300 CLS procedures.

The risks of sympathetic trunk inactivation have been recognized in thoracic sympathectomy, and selective sympathicotomy (ramicotomy) has been reported under video-assisted thoroscopic surgery²⁰⁻²². The anatomical distribution of lumbar sympathetic nerves is different from thoracic nerves, which makes implementation of selective CLS possible (see **Figure 4** and explanation below).

The lumbar sympathetic trunk is located in front of the anterior fascia of the psoas muscle, and this location is relatively fixed (**Figure 1, Figure 4**). However, the lumbar sympathetic ganglia have large variations in their relative positions to the vertebral body and in numbers (2-6 in the general population, most commonly 4, maximum of 8) among different individuals. Even within the same individual, distribution of the ganglia is not necessarily symmetrical. In some cases, the ganglia are located beside the vertebral bodies, and in others, they are located beside the lumbar discs. The gray rami communicantes originate from the sympathetic ganglia, and the relative positions to the vertebral body from where they originate are highly variable, too. The relative positions to the vertebral bodies from where communicantes merge into the lumbar nerve roots tend to be consistent, because the locations of lumbar nerve roots are fixed. This makes it possible to target gray rami communicantes without open surgery.

The optimal injection area (**Figure 1**) also successfully avoids the lumbar arteries and veins across the vertebral body, reducing the risk of operative and postoperative bleeding. More importantly, the psoas muscle attached to the lateral side of the vertebral body becomes a natural protective barrier of the lumbar nerve root, protecting the lumbar nerve root behind the psoas muscle and ensuring that no major nerve damage occurs.

There have been no complications other than mild transient genitofemoral neuralgia, which occurred in less than 20% of all cases treated by selected CLS, and all spontaneously resolved within a few days at our hospital. The incidence, intensity, and duration reported in the literature were highly variable, with ranges between 5 and 66%, from mild to significant, and lasting days to years^{2,23-28}. The genitofemoral nerve originates from the L1/L2 segments of the lumbar plexus, then passes downwards and forwards along the psoas muscle and through the anterior fascia of the psoas muscle at approximately the L3 level. Injecting a small amount of drug behind the anterior fascia at L3/L4 would theoretically decrease the chance and degree of genitofemoral nerve damage.

Kuntz's fibers have been blamed for surgical failures of endothoracic sympathectomy²⁹. There are no published reports on Kuntz's fibers in lumbar sympathetic nerve. To ensure satisfactory and persistent sympathetic interruption in CLS, it is recommended to inject the 2 mL of phenol in the optimal area (**Figure 1B**) in the directions of both the head and feet. Moreover, if sympathetic interruption is not satisfactory, it is recommended to inject supplemental phenol to another optimal area or at the L5, which is preferred over injection of a higher dose in the same area. In this regard, the chances of inactivating gray rami communicantes may be highly increased, and a higher degree of safety can be achieved.

Gray rami communicantes are unmyelinated nerves, which are more vulnerable to phenol compared to myelinated nerves. In our experience, 2 mL of 5% phenol is usually sufficient for each injection site. We have used a 4 mL injection in an earlier case, and we gradually lowered the amount to 2 mL.

In summary, we describe the procedure of selective CLS, which targets gray rami communicantes and not the sympathetic trunk, and we emphasize the anterior fascia of the psoas major muscle as a protective barrier when performing selective CLS. The precise needle tract, accurate evaluation of the contrast agent spreading, and multiple injections with small doses of phenol are all critical in ensuring the success of selective CLS.

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DISCLOSURES:

The authors have nothing to disclose.

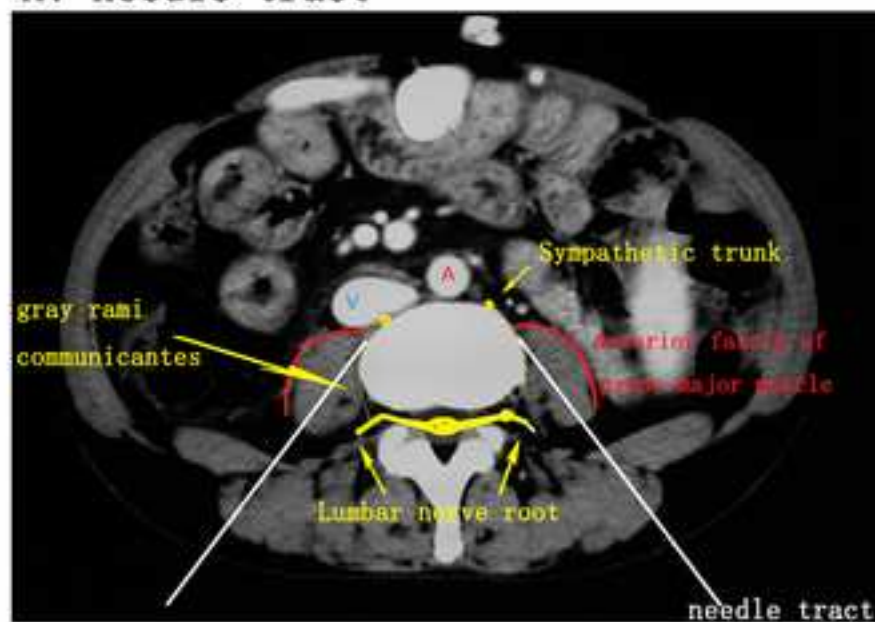
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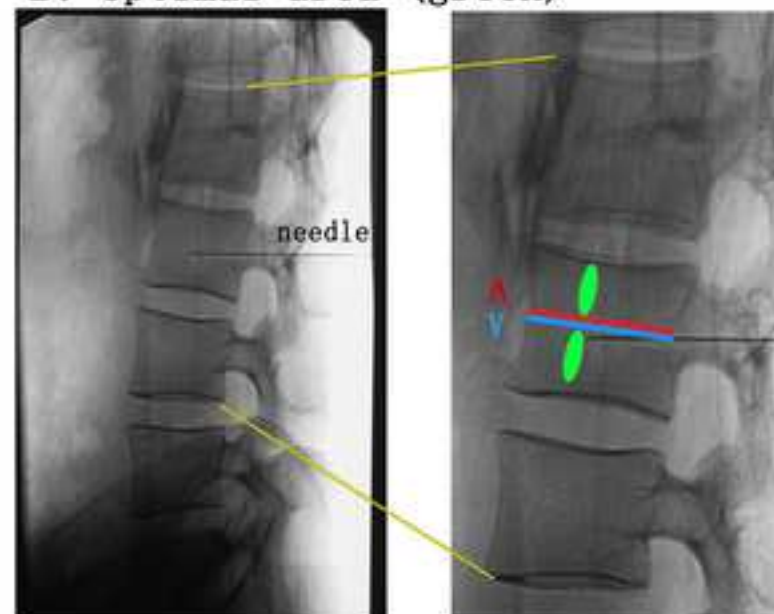
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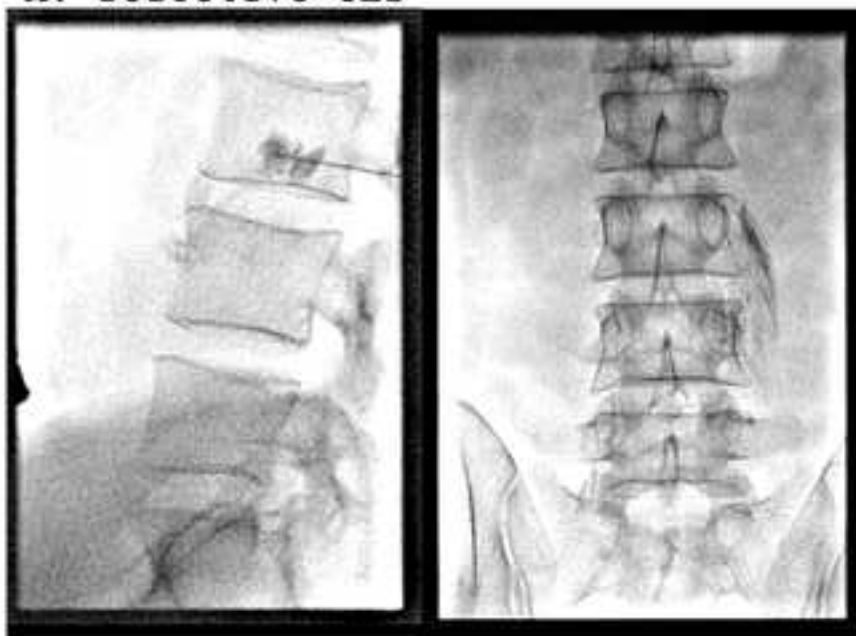
A: needle tract



B: optimal area (green)



A: selective CLS



B: conventional CLS

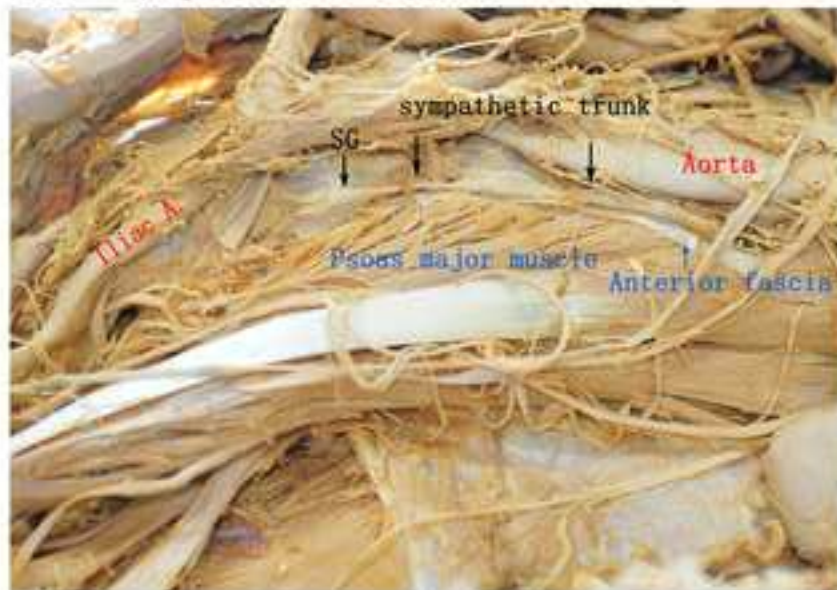


Figure 3

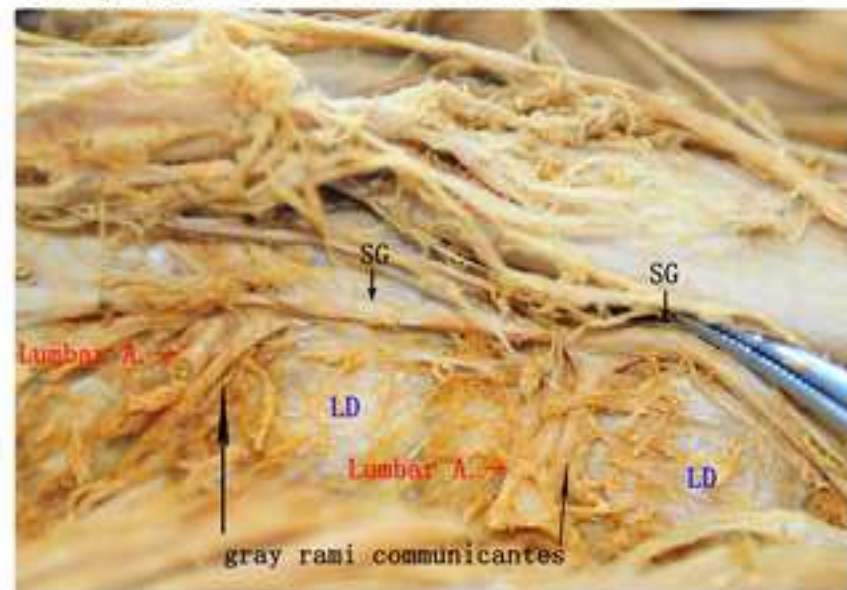
[Click here to access/download;Figure;photo3.jpg](#)



A: sympathetic trunk



B: gray rami communicantes



Name of Material/ Equipment	Company	Catalog Number
0.9% Saline solution	Chinese Dazhong Pharmaceutical Co.,Ltd.	8F84D7
10-cm 9# puncture needle	Peking University Third Hospital	Not Applicable
2% Lidocaine Hydrochloride Injection solution	Hubei Tiansheng Pharmaceutical Co.,Ltd.	20180434
5% Phenol diluted in aqueous solution	Peking University Third Hospital	Not Applicable
Angiography system (DSA)	Philips	FD20
Aseptic puncture kit	Peking University Third Hospital	Not Applicable
Contrast media (iodixanol injection; 320)	GE Healthcare	14160155
Infrared frontal thermometer	OMRON health care (China) Co.,Ltd.	MC-720
Iodophors skin disinfectants	Shanghai Likang Disinfectant Hi-Tech Co., Ltd.	20180404
Sterile surgical gloves	Beijing Ruijing Latex products Co., Ltd.	2018070352
Syringes and needles 10 mL	Shandong Weigao Group Medical Polymer Co.,Ltd.	20180711
Syringes and needles 5 mL	Shandong Weigao Group Medical Polymer Co.,Ltd.	20180721

Comments/Description
10 mL x 2
7# for children
5 mL x 2
10 mL
have X-ray fluoroscopy function
6 pieces of surgical towel, gauze, cotton balls, blood vessel forceps, etc.
320 mg I/mL
10 mL x 2
5 mL x 1



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