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Adoption of Novel Nano Bio-vascular Stent in Carotid Artery Stenosis Stent Intervention and Perioperative Nursing Analysis

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ABSTRACT

This work was developed to explore the adoption value of bacterial cellulose (BC) and heparin (He) combined with novel nano bio-vascular stents in carotid artery stent implantation, as well as the nursing methods and effects during the perioperative period. Based on the BC artificial blood vessel preparation method, the BC-He novel nano bio-vascular stent was fabricated after the modification of the medium method. Infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), and X-ray electron diffraction (XRD) were performed to analyze the crystal structure and chemical structure of the material. In addition, scanning electron microscope (SEM) and transmission electron microscope (TEM) were employed to observe the micro-morphology of the stent. The mechanical properties and thermal stability of the materials were also characterized. Then, with 98 patients undergoing carotid artery stenting (CAS) as the research object, BC-He novel nano bio-vascular stent was applied to treat patients with arterial stenosis. According to different nursing methods, patients were assigned to the conventional nursing group (group A) and perioperative nursing group (group B). The postoperative complications, nursing effect, and satisfaction degree of the two groups were compared. It turned out that the BC-He novel nano bio-vascular stent was a kind of micro-mesh structure. There were characteristic absorption peaks of BC and He in BC-He, and there were N and S from He. Moreover, it also contained BC and He characteristic diffraction peaks, its tensile strength was significantly lower than BC, and its thermal stability was higher than BC. The preoperative carotid artery stenosis ranged from 50 % to 75 %, and the postoperative stenosis rate of restenosis patients treated with BC-He novel nano bio-vascular stent was less than 10 %. In addition, there were 92 patients (93.88 %) whose symptoms improved or markedly improved within 1 to 2 weeks after the operation, and 78 patients (79.6 %) had improved hemodynamic parameters. The incidence of postoperative complications in group A was dramatically superior to that in group B (P < 0.05). The total effective rate of nursing care and the degree of nursing satisfaction in group B were better than those in group A (P < 0.05). In short, BC-He novel nano bio-vascular stent had good mechanical properties and thermal stability, which was a safe and effective material for the treatment of carotid artery stenosis. In addition, the perioperative nursing method was effective and was of certain clinical adoption value.

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Introduction

Carotid artery stenosis is a major risk factor for ischemic stroke, and about 7 % - 20 % of ischemic stroke is caused by the carotid artery (1). With the development of medical technology, endovascular stenting has been used to reduce the stenosis of blood vessels and restore the normal level of blood supply to the brain (2). With the development of vascular stent technology, carotid artery stenting (CAS) has become one of the main methods for the treatment of carotid stenosis. Its characteristics are that the incision of the operation is small or even invisible, simple operation method, and a short recovery period (3). In-stent restenosis (ISR) after CAS is the most common complication after carotid stenting (4,5), which will seriously affect the long-term effect of carotid stenting. Stent material selection, carotid artery stenosis criteria, follow-up time and, hospital medical level are also important factors affecting the efficacy. Organ tissue disorder is one of the serious problems that threaten human health, and the common treatment methods are organ transplantation and tissue repair (6). The clinical effect of artificial device repair is excellent, but the natural donor source for transplantation and repair is very limited. Therefore, the treatment methods are limited to vascular stent reconstruction, drug therapy, and artificial organ devices (7). The disadvantage of these methods is that

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they can't replace the functions of the original organs and tissues, and do not restore by themselves, and can't exist in the human body for a long time(8). Therefore, people began to use biological activities as tissue substitutes to study biological materials. Nanomaterials, also known as biomedical materials, can be used to improve the diagnosis, treatment, replacement or biological function of damaged tissues or organs (9).

Although some biological materials in clinical applications have not been designed as medical materials, with a deepening understanding of the immune system, biological materials can be accepted by human tissues (10). In the late 1980s, with the rapid development of biotechnology, people began to apply biotechnology to the development of biomaterials and put forward the concept of biomedical materials. Bacterial cellulose (BC) was discovered by Brown et al. (11). Many bacteria can synthesize cellulose. Cellulose produced by cellulose bacteria is called BC. Sämfors et al. (2019) (12) prepared BC artificial blood vessels suitable for artificial blood vessels. Ten kinds of experiments were carried out, and different carrier materials were used, including dialysis tubes, silicone tubes, cotton cylinders, and double-deck glass tubes. Several carrier materials were selected through materials, with surface or internal ventilation. Pressure and conditions are changed, such as observing the production time of BC. Most importantly, the biocompatibility can be reduced by changing the diameter of the carrier material, and the artificial scaffolds with a minimum diameter of 1.2 mm can be manufactured (13). In summary, researchers prepared BC vascular scaffolds by various methods but did not study the biocompatibility of BC in detail. Biocompatibility is an important parameter for evaluating biomaterials. The biocompatibility of vascular scaffolds directly affects the success of material transplantation, so the method to improve the biocompatibility of vascular materials is an important topic in the study of vascular scaffolds (14).

In this study, 98 patients with CAS were selected as the research object to explore the application value of BC and heparin (He) composite new nano vascular stent in CAS and perioperative nursing methods and effects.

Materials and methods

Experimental objects

A total of 98 patients with CAS were selected as the research objects. The novel nano bio-vascular stent was used to treat patients with arterial stenosis. According to different nursing methods, the patients were divided into a routine nursing group (group A) and a perioperative nursing group (group B). The incidence of postoperative complications, nursing effect, and satisfaction of the two groups were compared.

Inclusion criteria: (i) the diagnostic criteria for arterial stenosis have clinical symptoms. (ii) Patients' age is above 18 years old. (iii) No other sudden diseases (such as hypertension, heart disease, diabetes, hypertension)

Exclusion criteria: (i) patients without informed consent. (ii) Patients with arterial infarction within 2 months. (iii) Patients under 18 years old. (iv) Patients with poor coagulation function. (v) Patients who can't be followed up. In this study, a total of 98 patients with arterial stenosis met the above inclusion criteria and exclusion criteria. This study was approved by the medical ethics committee of China-Japan Union Hospital, and the family members of patients signed informed consent.

Preparation of BC-He composites

The BC material was fermented by a multi-layer glass tube. The PH of the solution remained unchanged, and 1 % He was added. After high-temperature sterilization, it was put into the container to adjust the PH to neutral. About 30 % BC-He was inoculated into bacterial culture solution, placed in a biochemical incubator, and propagated at room temperature. Three days later, BC-He composite membrane was obtained. BC-He composite membrane bath, the temperature was set to 80℃, using 0.1 % concentration of sodium hydroxide mixed digestion, and then deionized water was added to make the solution neutral (15).

Material characterization method

Fourier infrared spectroscopy test: drying measurement, Bio-Rad FTS 6000 infrared spectrometer was used to perform Fourier infrared spectroscopy test, transmission method was used, and the instrument scanning speed was set to 5° / min.

X-ray diffraction analysis: drying measurements of BC-He composites were performed using RigakuD / MAX2500v / pc X-ray diffractometer. The working current was 170.0 mA, the working voltage was 60.0 l V, the scanning range was 5° to 35 °, and the scanning speed was set to 5° / min.

X-ray photoelectron spectroscopy analysis: BC-He composite was dried and measured by 1600 X-ray photoelectron spectrometer. The resolution was 0.7 eV, the sensitivity was 80 kcps, the angular resolution was 5° - 90°, the operating voltage was 15 kV and the power was 400 W.

Scanning electron microscopy: BC-He composites were frozen in liquid nitrogen, dried in a vacuum for 30h, and sprayed with gold. Scanning electron microscopy was used to observe the surface morphology of the samples and the working voltage was15 kV.

Transmission electron microscope: composites were crushed in an emulsion state. Alcohol was added to the ultrasonic dispersion for 20 min, and the droplets were absorbed onto the support membrane and dried. Field emission transmission electron microscopy was used to observe the microstructure of various samples.

Tensile property test: it was carried out on Testometric M350. The sample size was 4 × l cm^2, and the thickness was 0.2 + 0.05 mm. Three samples were used as a group to test tensile strength.

Thermal performance test: the sample was dried, and the thermal properties of the material were analyzed by scanning calorimeter. The heating rate was 10°C / min, the temperature range was 30°C-800°C, and the nitrogen flow rate was 100 mL/min.

Surgical treatment

Blood examination, liver, and kidney function, electrocardiogram and other examinations were performed before the operation, and the operation-related taboos were carried out for all patients. Head examination was performed to master the physical condition of the patients. CT or ultrasound was used in advance to detect whether there were new cerebral infarction and infarction sites and whether there were tumors or other brain diseases. Patients were treated with 100 mg aspirin 3 days before the operation. They could not eat 6h before the operation. They were given phenobarbital 30 minutes before operation, and dopamine, atropine, magnesium sulfate, and other drugs were prepared. After iodine disinfection, the treatment cloth was paved. After local anesthesia with 2 % lidocaine, the thigh artery was punctured by Selinger's operation and inserted into the arterial sheath. Firstly, the 6f catheter was guided to the carotid artery, and the BC-He stent was delivered to the appropriate position. After accurate positioning, the bracket was stripped under appropriate pressure. During the operation, the patients continued to be monitored for blood oxygen, blood pressure, and ECG. Postoperative supine position, sandbag pressure for 4h, the maximum pressure of the bag was 450 mmHg to prevent excessive fluid flow or liquid packaging bag damage. After extubation, the artery was forced to lie in the puncture point and supine position for 24h after 40 minutes of the supine position. Because of the bleeding, the wound was paid special attention. It was observed whether the pulsation of the dorsal artery of the foot became weak, and the skin color, and temperature of lower limbs. If the foot discolored, that meant the possibility of thrombosis. The anticoagulants were used postoperatively. The stent may form stenosis or occlusion when compression hemostasis. Most stent deformations can be corrected by anticoagulants.

Statistical method

Graphpad prism 5.0 software was used for the statistical processing of each data. The data were expressed as mean ± standard deviation, and SPSS 20.0 was used to analyze the differences between groups. The *t*-test of independent samples was used to detect vascular diameter experiment and angiogenesis experiment, and $P < 0.05$ indicated statistical difference.

Results and discussion

Characterization of BC-He composites

As shown in Figure 1, the absorption peaks at about 2700 cm^{-1} and 3300 cm^{-1} for 1000 - 4000 cm^{-1} FTIR of BC are -OH and $-CH_2$ stretching vibrations. Figure 2 is the local He diagram. The absorption peaks at about 1125 cm^{-1} and 1300 cm^{-1} are the stretching vibration absorption peaks of ether bond and carbon-carbon double bond.

Figure 3 is the characteristic absorption peak of BC-He. The absorption peaks appear at about 2700 cm^{-1} and 3300 cm^{-1} and at about 1125 cm^{-1} and 1300 cm^{-1}, showing that the product contains the characteristic structure of BC and He and indicating the existence of BC-He.

Figure 4 is the XPS diagram of BC-He, which shows the characteristic peak of S, while BC is only composed of C, H, and O, so it can be judged that He is successfully introduced.

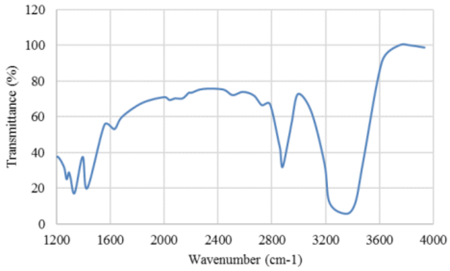

Figure 1. FTIR of BC.

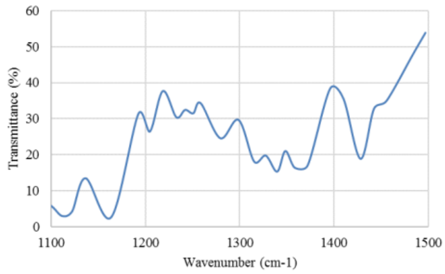

Figure 2. FTIR of He.

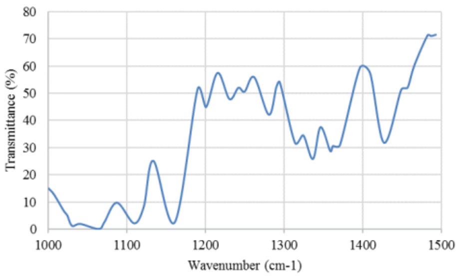

Figure 3. FTIR of BC-He.

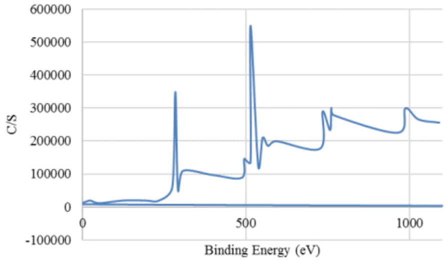

Figure 4. XPS of BC-He.

The XDR diagram in Figure 5 shows that there are not only the diffraction peaks of BC but also the amorphous structure peaks of He. The typical amorphous diffraction peaks appear at about 14° and 23°. The crystallinity is calculated by Jade. The samples are BC-He crystals, and the results are 87.2 and 51.1. The crystallinity of BC-He decreases, indicating that He will affect the crystallinity of the product, leading to the failure of normal crystallization of BC.

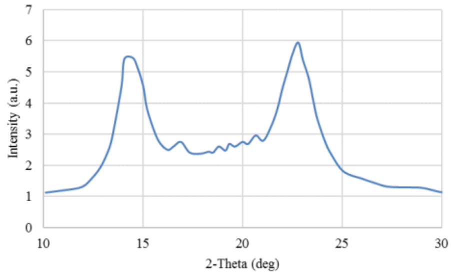

Figure 5. XDR of BC-He.

Morphological characteristics of BC-He composites

Figure 6 is the TEM image of BC-He. The fibers of BC-He composites are interlaced, with clear structure and lattice. The fibers have two characteristic regions, the crystalline region (crystal region) and the amorphous region. The crystal plane spacing of the two materials is about 0.32 nm. The crystalline region and amorphous regions of the BC-He composite structure coexist, and the He material does not affect the crystal plane spacing of BC.

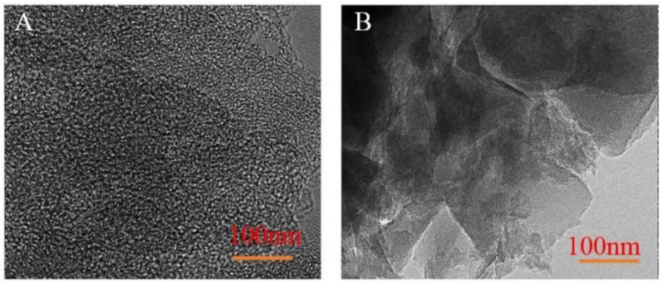

Figure 6. TEM images of BC-He.

Figure 7 is the SEM image of BC-He. The structure of BC-He fiber is disordered and staggered, and the nano-structure makes the fiber combine more closely.

The structure can be observed by SEM, indicating that the BC-He configuration is normal.

Figure 8 shows the tensile strength of BC-He composites. Compared with BC, the tensile strength of BC-He composites is increased ($P < 0.05$).

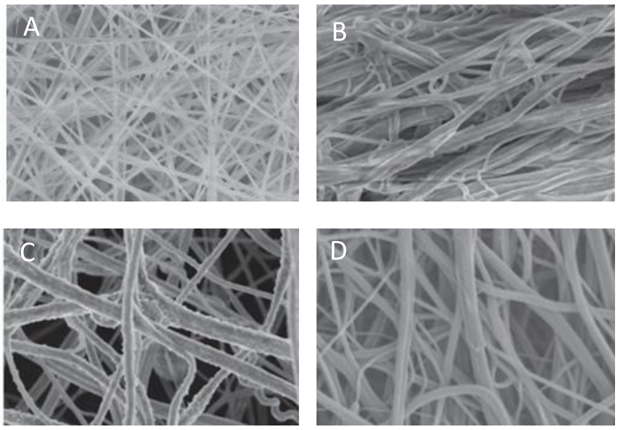

Figure 7. SEM images of BC-He (A, B, C, and D are different angle observation structures)

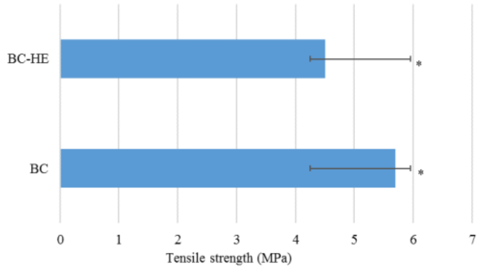

Figure 8. Tensile strength of BC-He composites. *indicates the data between groups are statistically different, $P < 0.05$

Thermal stability analysis of BC-He composites

Figure 9 is the TG curve of BC-He composites. The heat loss at 30 - 270° is caused by dehydration. The material will lose a lot of water in this section, not only the water wrapped by the material but also the water combined with hydrogen bonds. When the weight is greater than 270°, it is mainly due to the instability of the material. After 700°, it is a stable weight and has high thermal stability.

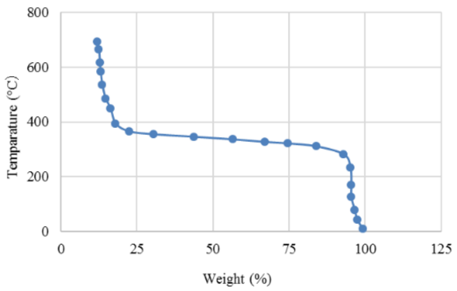

Figure 9. TG curve of BC-He composites.

Effect of restenosis after CAS

After reexamination, the vascular stenosis rate was less than 10 %, the degree of restenosis was significantly improved, the postoperative clinical symptoms were alleviated, and symptoms improved or significantly improved within 1 - 2 weeks. In the conventional nursing group, 97 cases had a postoperative stenosis rate < 10 %, and the incidence was 98.9 %. In the conventional nursing group, symptoms of 91 cases were improved or significantly improved within 1 - 2 weeks, and the incidence was 92.8 %. The hemodynamic parameters of patients were improved to 76 cases, and the incidence was 77.5 %. Perioperative nursing group postoperative stenosis rate < 10 % was 98 cases, the incidence was 100 %, symptoms of 92 cases were improved or significantly improved within 1 - 2 weeks, the incidence was 93.88 %, 78 cases of hemodynamic parameters improved, and the incidence was 79.6 %. The results are shown in Table 1.

Table 1. Effect of restenosis after CAS

		The postoperative stenosis rate was less than 10%	Symptoms improved or improved significantly within 1 - 2 weeks	Hemodynamic parameters of the patients were improved
Perioperative nursing group	Cases	98	92	78
	Rate	100 %	93.88 %	79.60 %
Conventional care group	Cases	97	91	76
	Rate	98.90 %	92.80 %	77.50 %

Evaluation of the perioperative nursing effect

The incidence of postoperative complications was compared between the two groups. The incidence of adverse complications in the conventional nursing group was 26 cases, and the incidence was 53.06 %. The incidence of adverse complications in the perioperative nursing group was 11 cases, and the incidence was 22.33 %. The data were statistically significant ($P < 0.05$). The results are shown in Figure 10A. The total number of effective cases of postoperative nursing in the two groups was compared. In the conventional nursing group, the total number of effective cases of nursing was 44, and the effective rate was 89.7 %. In the perioperative nursing group, the number of satisfactory cases of nursing was 49, and the effective rate was 100 %. The data were statistically significant (P < 0.05). The results are shown in Figure 10B.

The number of cases of postoperative nursing satisfaction in the two groups was compared. The number of cases of nursing satisfaction in the conventional nursing group was 36, and the effective rate was 73.4 %. The number of cases of nursing satisfaction in the perioperative nursing group was 47, and the effective rate was 95.9 %. The data were statistically significant (P < 0.05). The results are shown in Figure 11.

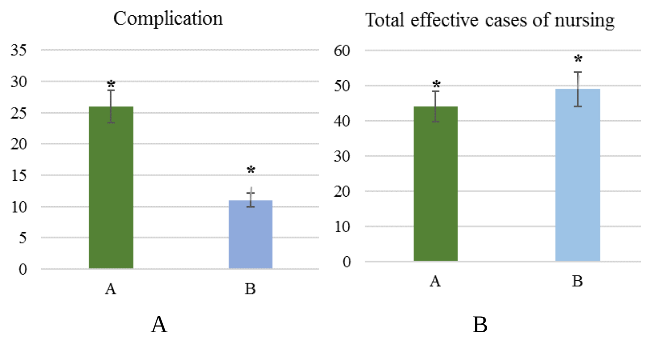

Figure 10. Comparison of incidence of postoperative complications and total effective cases of postoperative nursing between the two groups. (A is the incidence of postoperative complications. B is the total effective number of postoperative nursing. * represents that the data between groups were statistically different, P < 0.05)

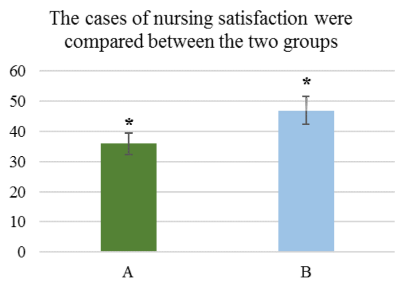

Figure 11. Comparison of two groups of postoperative nursing satisfaction cases. (* means that the data between groups were statistically different, P < 0.05)

When patients are diagnosed with CAS restenosis or corresponding symptoms, stenting, carotid artery bypass, and carotid endarterectomy can be used for treatment (16). The choice of surgical methods is the focus of current research, the original simple balloon dilatation is the initial treatment, and then the use of metal stents, as well as a variety of balloon dilatation, and stent selection has been discussed (17). Scaffolds are selected for better endovascular treatment. The use of nano-scaffolds can generate continuous radial pressure after transplantation, which can prevent restenosis. Because nano-scaffolds have various excellent characteristics, such as easy availability of materials, good biocompatibility, response to vascular elastic contraction, accurate positioning, safe, and effectiveness, it is gradually adopted by the public, and is widely used in the treatment of carotid artery stenosis (18). Studies showed that nanocoatings can be used to strengthen the basic structural strength of materials and increase the corrosion resistance of materials (19). Based on this, a novel nano bio-vascular stent was prepared and applied to the treatment of carotid stenosis.

The stenosis of the superior arch of the great artery includes carotid artery stenosis, vertebral stenosis, and subclavian movement. The stenosis of the superior arch of the aortic artery is a major cause of ischemic stroke (20) Patients with fewer traumas recovered quickly with low mortality and disability. Patients with arterial stenosis received endovascular stenting and perioperative nursing. Postoperative observation, drug therapy, and complications nursing can reduce postoperative complications and timely detect acute occlusion of blood vessels (21) Scotland et al. (2019) (22) introduced a small diameter BC tube called microtubule surgery, which was placed into the carotid artery of mice as a scaffold. Through research and observation, the scaffold material covered a layer of cells, indicating that endothelial cells formed and filled closely with each other. The results of this study showed that the scaffold material quickly adhered to endothelial cells and formed an ideal cell layer, indicating that BC had good biocompatibility and blood compatibility. Khoddami et al. (2020) (23) prepared BC vascular scaffolds, but there is no in-depth study on the biocompatibility of BC. Whether biocompatibility meets the requirements is a major standard for whether biomedical scaffolds can be put into use. Biocompatible materials can be applied to practical use. Therefore, modern research not only focuses on the stability and tensile strength of Nano-biomaterials but also on biocompatibility (24-27). In this study, He assisted BC tube, which can increase biocompatibility and strength and is applied to the treatment of carotid stenosis.

Conclusions

In this study, in order to improve the therapeutic effect of carotid artery stenosis, a novel nano bio-vascular stent was prepared and applied to the interventional operation of the carotid artery stenosis stent. Combined with perioperative nursing, the effect of nano bio-vascular stents on the treatment efficiency of patients was explored. The results showed that BC-He composite nano bio-vascular stent had good mechanical properties and thermal stability, and was a safe and effective treatment material for carotid artery stenosis. The effect of perioperative nursing was significant, and it had a good clinical application prospect. However, there are still some limitations in this study. For example, there are fewer participants in the study, which can't constitute a large number of samples, and more biocompatible materials can be used in material selection. In conclusion, the results of this study have important guiding significance for the improvement of clinical treatment of carotid stenosis.

Acknowledgments

Not applicable.

Conflict interest

The authors declare that they have no conflict of interest.

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