

Electrochemical Therapy of Tumors

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What is Electrochemical Therapy (EChT)

Inserting electrodes (special produced by platinum) into tumor and connecting its with EChT apparatus, direct electric current arouse strong chemical reactions around electrodes and lead degeneration and necrosis of tumor cells. It is a new type method to treat tumor without surgical resection. The final result is caused by direct electric current inducing chemical reactions, so it is called EChT.

Historical note

The study of effectiveness of direct current on biologic tissues has a long history. In 1895, a physiologist tried to insert electrode into a dog's brain and gave D.C. stimulation on it, he found necrosis occurred in brain tissue around electrode. After that some other doctors have done a lot of experimental works about the reactions of biologic tissue for direct current.

However, the clinical application of this modality was initiated by the Swedish radiologist, Bjorn Nordenstrom. In 1983, he published a book in which he described his theory of biologically closed electrical circuits (BCEC) and the results of research for EChT on malignant tumors in animals based on this. He also reported the results of EChT on 20 lung cancer patients with 26 tumors in which he used the "skinny needle" he had developed for biopsy purposes as an electrode. Follow-up after 2 to 5 years revealed that 12 tumors had either disappeared or were markedly reduced in size.

But the real widely application of the technique has begun in China (China-Japan Friendship Hospital as the center of this application) after it was introduced to the country in 1986. The advantages of EChT include less injury, easy manipulation, safety and efficiency. It provides the chance of treatment for tumor patients to whom operation, radioand/ or chemotherapy is not indicated or ineffective.

Experimental studies on mechanism of EChT

It has been well established that tumor cells are more sensitive to certain changes in the environment than adjacent normal cells, which is the basis of application of radio-, chemotherapy, hyperthermia, microwave and laser therapy for treatment of tumors. Many pathological changes occurred in the tumor tissue when D.C. was act on it, such as pyknosis of nuclei, disruption of cell membrane, disappearance of mitochondria and coagulation and necrosis of nuclear protein

The publication of Nordenström's work for lung cancer aroused many researchers' attention and interest in this field. A number of scientists did animal experiments in order to make clear the mechanism of action, the indication of clinical application and improvement of the manipulation of the method. In animal experiments, histopathological studies have demonstrated that the killing effect of EChT on the tumor tissue surrounded anode area differs from that around the cathode area. The tumor tissue surrounded anode area showed necrosis of coagulation feature: cell structure was destroyed, pyknosis of cells, denaturation and coagulation of protein. While tumor tissue surrounded cathode area showed necrosis of liquefaction in nature: cell structure totally disappeared, water molecules accumulated due to the presence of positively charged sodium ions and large molecules of protein was swollen and dissolved.

Though the features of changes are different in anode and cathode areas, the killing areas of both electrodes are about the same, i.e. the radius of killing effect is 1 cm.

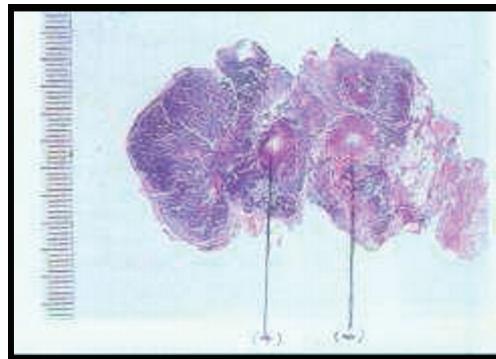
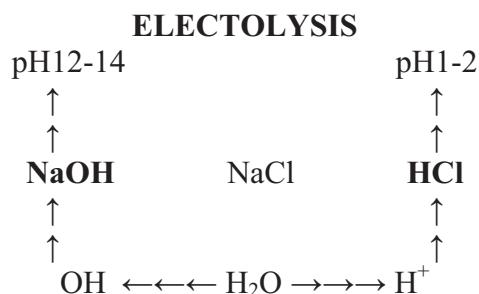


Figure 1. The killing effect of cathodes & anodes was similar

On the basis of large amount of animal experiments and clinical pathological examination, the mechanism of killing action of EChT has been confirmed as electrolytic effect of direct current. The killing action of DC per se is limited only around the surface of electrode. To expand the killing effect are the substances resulted from electrolysis of water and electrolytes (NaCl and H_2O), i.e. NaOH and HCl diffused from around electrode to a certain distance. Na^+ ion formed by electrolysis will move toward cathode area and combine with OH^- ion to form NaOH , which will result a strong alkaline (pH 12-14) environment. While Cl^- ion formed will accumulate around anode area and combine with H^+ ion to form HCl , which is strong acidic (pH 1-2).



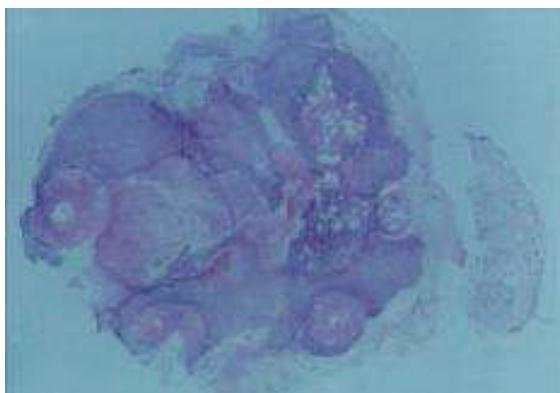
The strong alkalinity and acidity are the main killing factors of the therapy. Hence, it is seen during the application of EChT there is large amount of foams oozed out from the periphery of electrodes releasing Cl_2 and H_2O_2 .



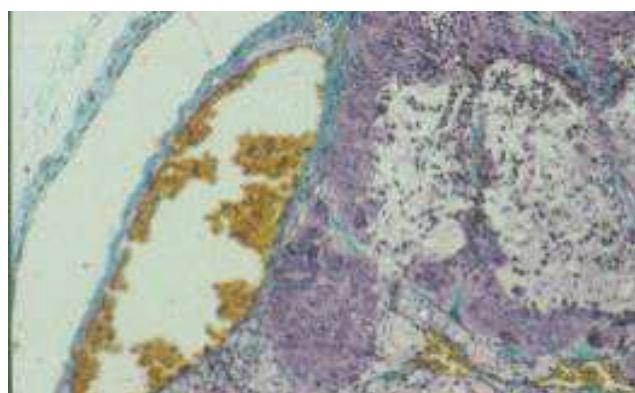
Figure 2. The figure of cancer cells disappeared and a mass of air bubbles came forth 10 minutes after EChT

The mechanism of EChT for treatment of tumors is summarized as follows:

- (1) Electrolysis by direct electric current changes pH of environment which results in biological effect;
- (2) Direct electric current could increase the permeability of cell membrane of tumor cells. Ions and Cl₂ could go inside and kill tumor cells;
- (3) Activity of enzymes in plasma was inhibited, proteins denatured, coagulated and necrosis occurred
- (4) Electrolysis makes distribution of irons changed, which results in coagulatory necrosis around anode and edema around cathode



(low power lens)

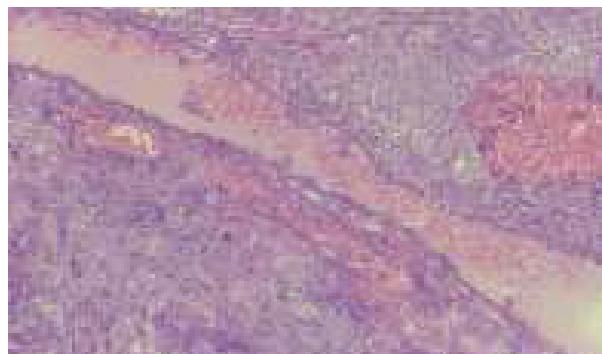


(high power lens)

Figure 3. The anode made tumor tissues dehydrated and carbonized protein coagulated and necrosis



(low power lens)



(high power lens)

Figure 4. Cancer cells were dissolved and breakdown, congestion and edema of tissue were represented in the area of cathode

- (5) Extensive embolism occurred in blood vessels in anode area.

Because severe edema in cathode area, microcirculation was damaged. Hence, the blood supply to tumor cells is interrupted

- (6) White blood cells and T lymphocytes accumulated in anode area, which may be helpful to kill tumor cells. At the same time, the negatively charged tumor cells are adhered to anode area and metastasis of tumor cell are halted

- (7) The damaged fragment of tumor cells by direct electric current could be the antigen to improve the immune system of the body

Clinical application and effectiveness of EChT to treat tumors

After the clinical applications of EChT to treat cancer reported by Nordenström in 1983, the China Japan Friendship Hospital in Beijing took the lead to apply the method in clinical, and they have finished more than thousands operations for many kinds of tumors from then on.

Several years ago, we summarized the clinical effectiveness of 8641 cases of malignant tumors treated by EChT after long-term follow-up in 82 hospitals of China from 1987 to 2000 and 2069 cases of benign tumors treated by EChT in 16 hospitals from 1995 to 2000.

Malignant Tumors

Superficial tumors	(No.)	visceral tumors	(No.)
Skin	1058	Esophagus	1595
Breast	744	Lung	1113
Head and face	698	Liver	961
Throat	21	Prostate	20
Metastatic superficial lymph nodes	461		
Thyroid	350		
Vulva	337		
Melanoma	326		
Chest & abdominal wall	272		
Oral cavity	238		
Parotid	184		
Rhabdomyosarcoma	133		
Others	130		
Total	4391		3710

Table 1. The classification of 8641 cases

Age	No.	Male		Female	
		n	%	n	%
20~40	1284	765	59.6	519	40.4
41~60	4583	2901	63.3	1682	36.7
61~80	2485	1334	53.7	1151	46.3
> 81	289	181	62.6	108	37.4
Sum	8641	5181	60.0	3460	40.0

Table 2. The age and sex of 8641 cases

	No.	I		II		III		IV	
		n	%	n	%	n	%	n	%
Visceral	3710	40	1.1	820	22.1	1725	46.5	1125	30.3
Superficial	4931	910	18.5	2099	42.6	1413	28.7	508	10.3
Total	8641	950	11.0	2919	33.8	3138	36.3	1633	18.9

Table 3. Clinical stages of 8641 cases

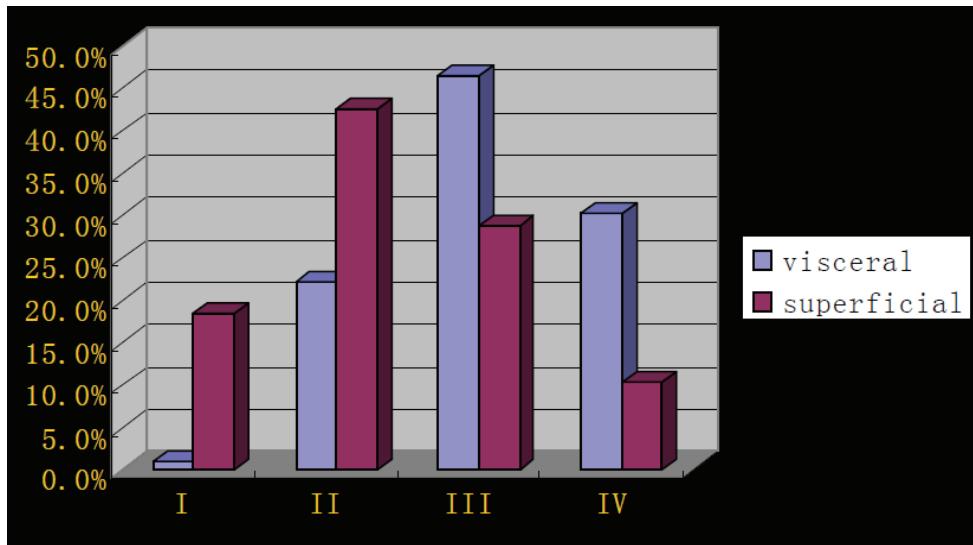


Figure 5. Clinical stage

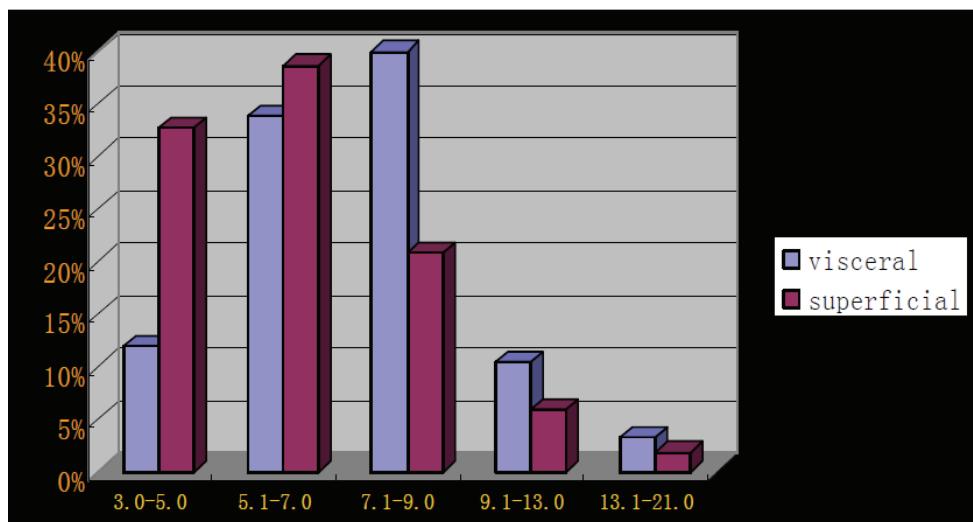


Figure 6. Tumor size

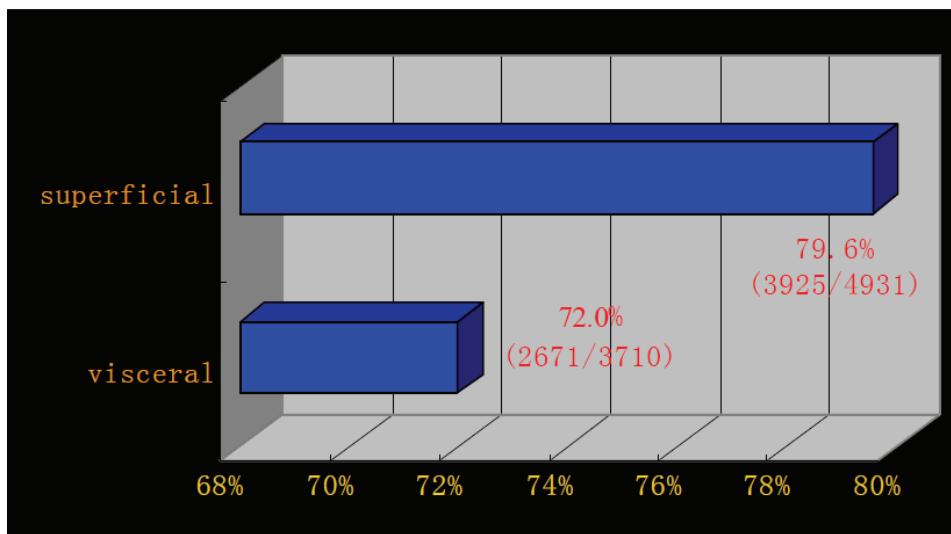


Figure 7. Clinical results treated by EChT ($CR+PR \approx 76.3\%$)

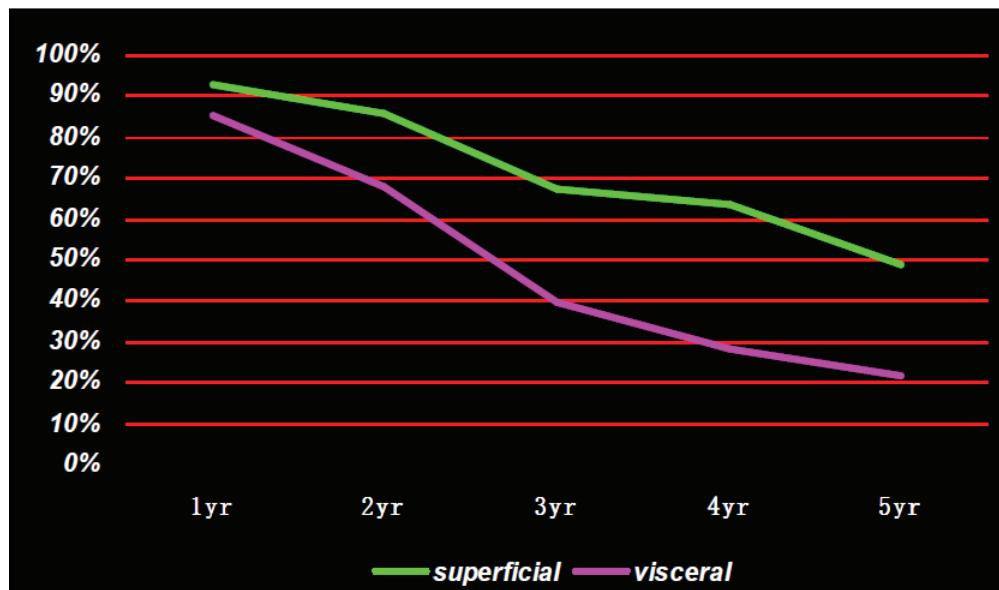


Figure 8. Survival rate

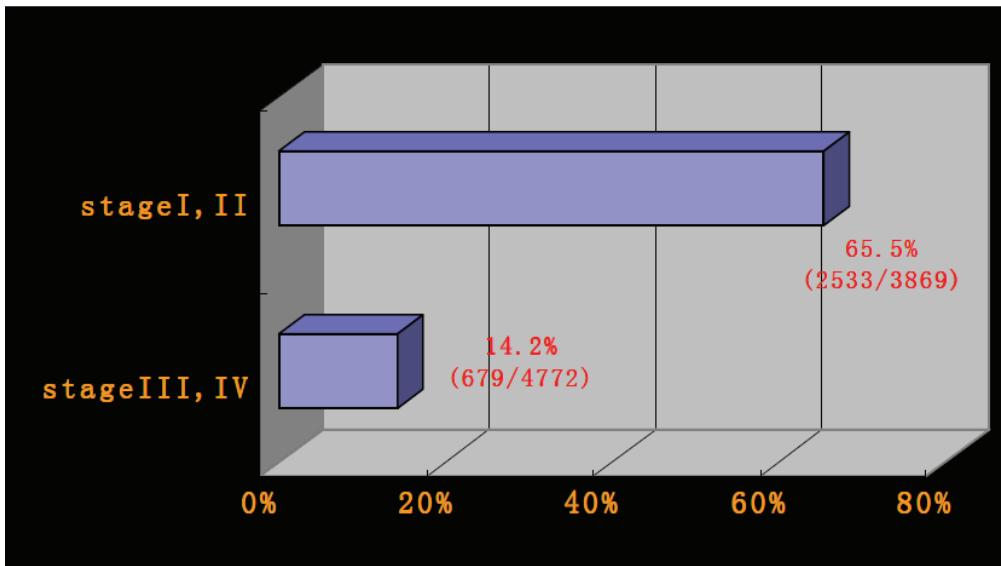


Figure 9. 5-year survival rate

Indications of EChT

When a cancer patient is not suitable for surgical operation and/or radio-、 chemotherapy are not effective, EChT may show its special effectiveness.

The superficial tumors are well indications of EChT, such as cancer of head and face, breast cancer, parotid cancer, cancer of oral cavity, cancer of tongue, cancer of superficial lymph node, melanoma, rhabdomyosarcoma, cancer of vulva, cancer of penis, etc. Electrodes can be inserted accurately and arranged properly for those cases. Electric field for treatment can cover the whole cancer. Position and number of electrodes might be adjusted at anytime necessary.

EChT could have satisfactory result if other treatment is ineffective especially for late stage patients that have ulceration on the tumor (for example, local recurrence of operated breast cancer) which was not effectively treated in the past.

EChT can be a complementary method for surgical operation also. For the tumors which cannot be resection during thoracotomy (central type of lung cancer, mediastinal tumor), electrodes could be

inserted accurately to treat tumor. It is the same for abdominal surgery and gynecological operation for cancers not being resection (liver cancer, kidney cancer, pancreas cancer, ovarian cancer, etc.). Symptoms could be relieved and there is effectiveness to certain extent.

Example cases:

Case 1. An abdominal surgery was tried to resect a liver tumor but failed. Before operation and CT scan.

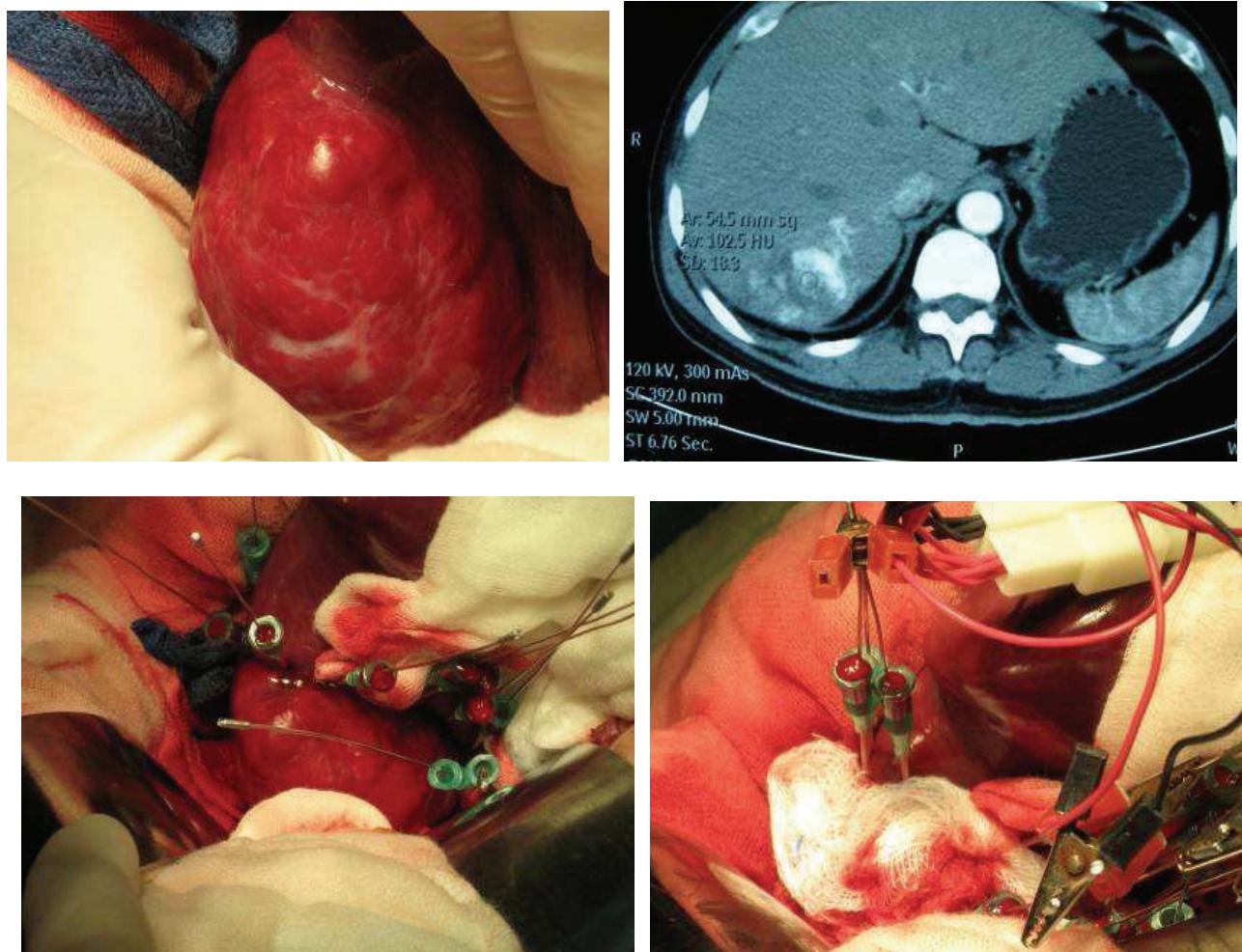


Figure 10. EChT was applied as a substitute treatment

Case 2. Tumor of post-peritoneum. F, 28ys. Tumor of pelvic cavity, CT scan showed the tumor 13X10X7cm. Left ureter was displaced to the other side. There is serious adhere between the tumor and surrounding tissue and the surgical resection was failed.



Figure 11. CT scan imaging

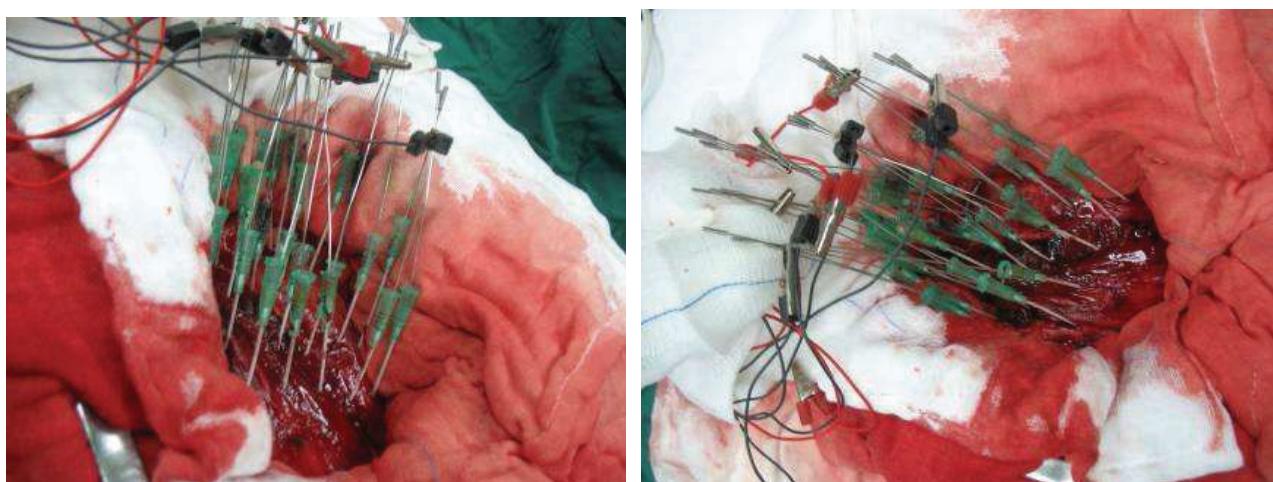


Figure 12. EChT was applied as a substitute treatment. Pathologic diagnosis: tumor of fusiform cell

Case 3. M,53ys. Left thoracic & abdominal tumor, 14X8X4cm. Both thoracic and abdominal cavity was opened but the tumor could not be resected. Pathologic diagnosis: neurofibroma.

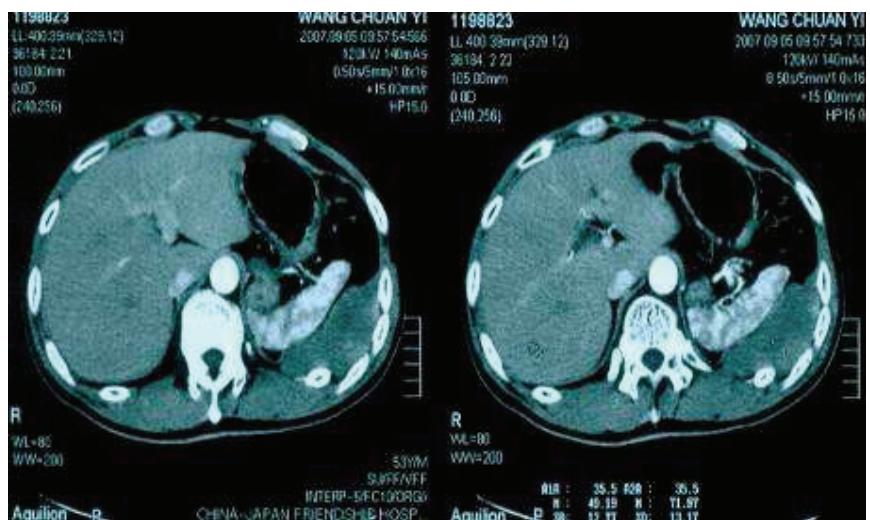


Figure 13. CT scan before EChT

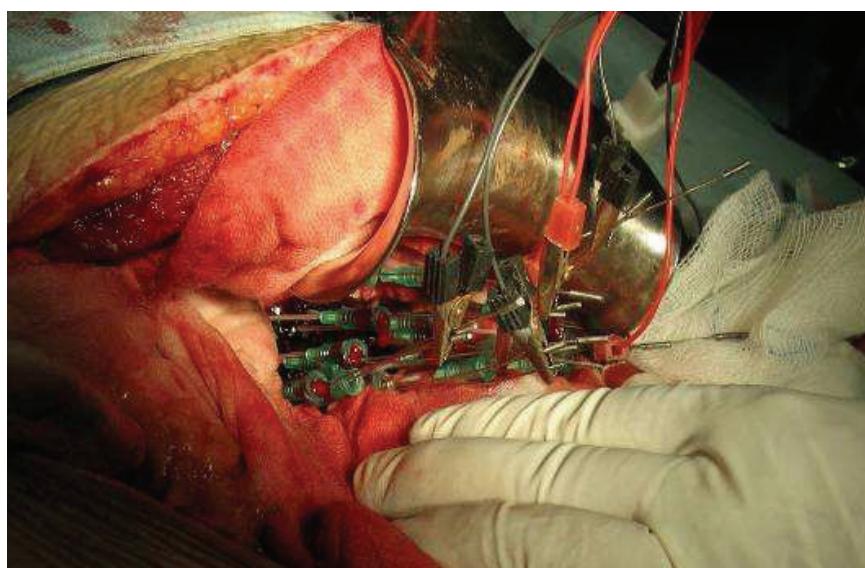


Figure 14. During EChT

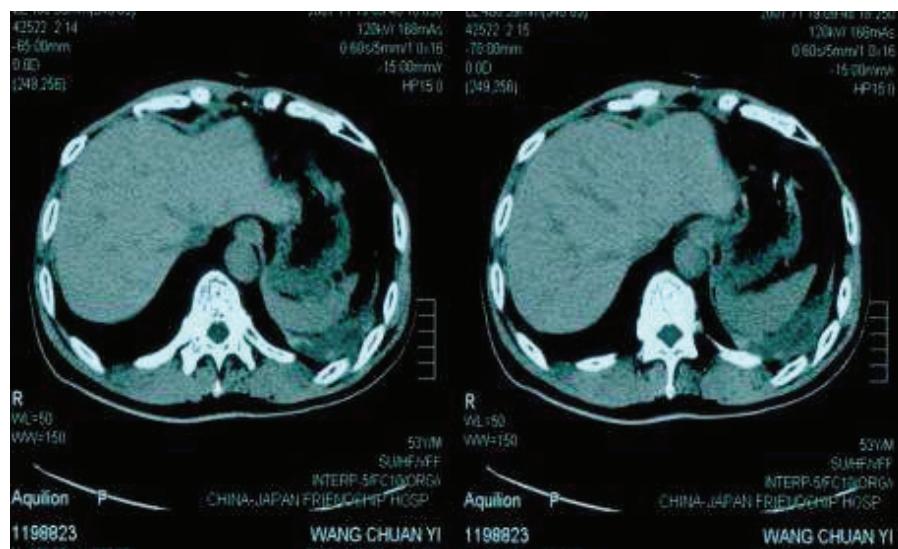


Figure 15. 13ms after EChT. The patient was followed up for 13 months and recovered well

Complications of EChT and its management

EChT is less traumatic, so even old or weak patients could accept this treatment. Slight fever, increase of WBC account after EChT might occur. It usually lasted for 3-5 days and return to normal automatically.

DC would not be harmful to patients when it is under 30V, EChT is also a save method since the voltage used is much lower than 30 V.

But if the insulation cannula does not arrange properly, surrounding normal tissue and skin damaged by electrode will happen. It can be cure spontaneously.

Manipulation of Electrochemical Therapy

1. Method of Treatment

(1) Selection of Instrument and Electrodes

Instrument: Computer controlled ZAY-B multifunctional instrument is used. It has two outputs with data storage and print function. Electric current, voltage and electric quantity needed could be pre-set. Alarm system would be started when short circuit or disconnection occurs.

Electrode: Electrode is made of platinum with 0.7 mm in diameter and 160 mm in length. It has high electric conductivity and better anti-erosive properties. Needles are coated plastic catheter for insulation to protect normal tissue against electric damage.

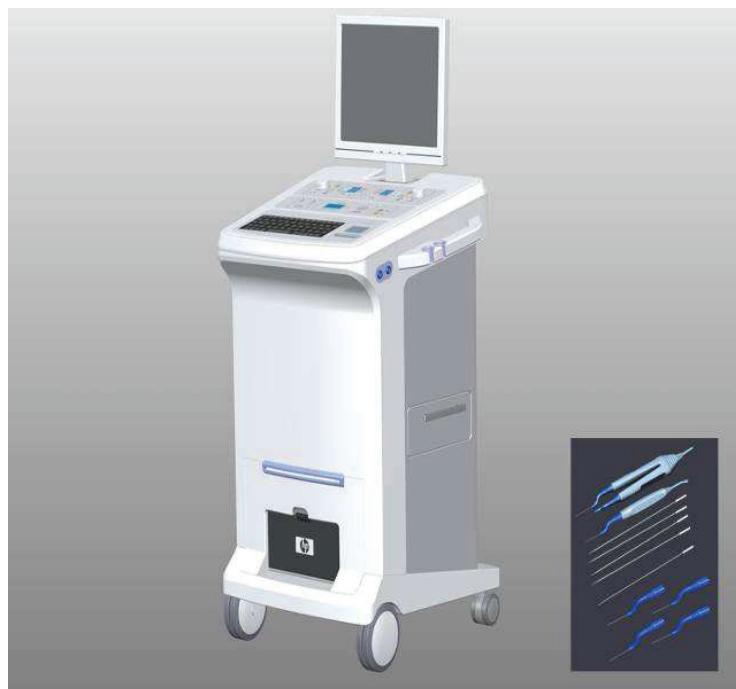


Figure 16. Electrochemical therapeutic apparatus and electrodes. Zay-B electrochemical therapeutic instrument and platinum electrodes. Made of China

(2) Manipulation

Cathodes are usually placed in the center of tumor and anodes in peripheral. However, both the cathodes and anodes could be placed one besides the other, alternately. Electrodes must be covered the whole tumor to avoid incomplete treatment. Insulating plastic tubes are used to protect normal tissue from injury due to electrolysis. Then electrodes are connected to the instrument to start treatment

The killing radius of each electrode is about 1.0 cm, the distance between two electrodes should be less than 1.5 cm. So the number of electrodes needed could be calculated according to tumor size.

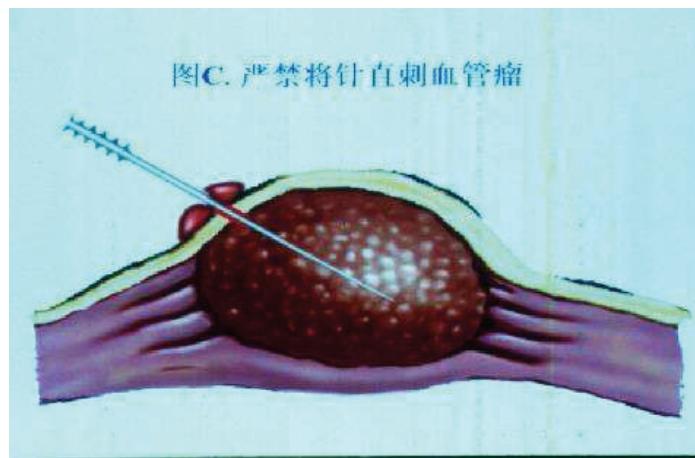


Figure 17. Incorrect method to insert a trocar into a hemangioma and induce in bleeding in the needle hole

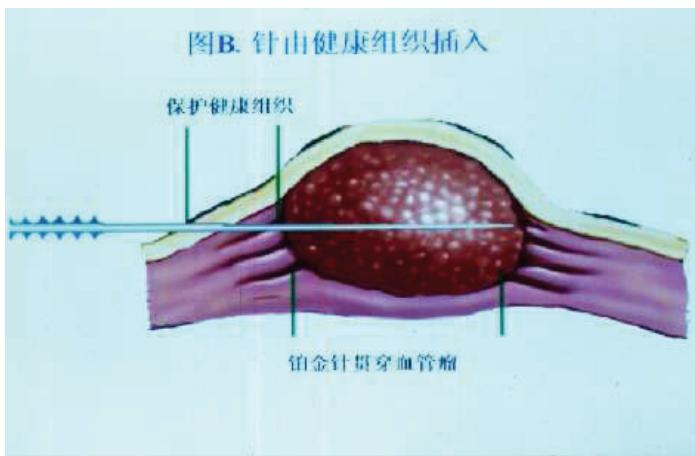


Figure 18. Correct method that trator is inserted into tumor through the normal tissue beyond the margin of tumor 2cm, bleeding is avoided and normal skin is protected



Figure 19. Pressing the hemangioma during EChT to extrude blood and necrotic liquid

There will be a rupture drop area of electric field between 2 electrodes when the distance of electrodes is over 2 cm. So 1.0~1.5cm will be the best choice of the distance between electrodes during EChT.

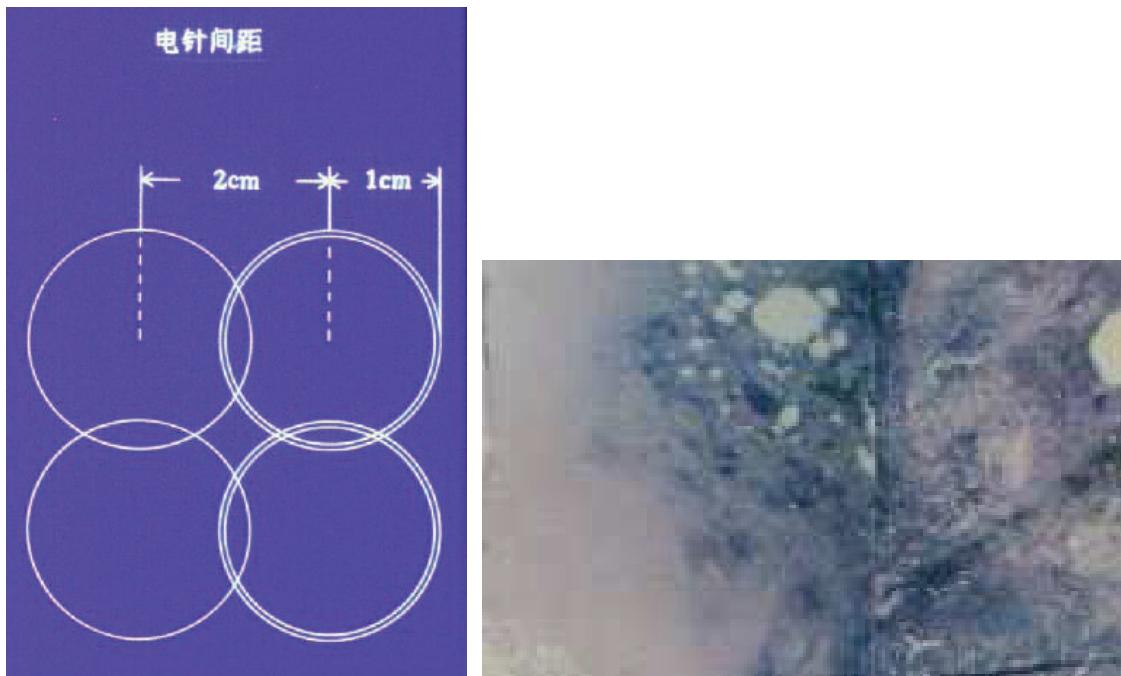


Figure 20. No remaining area left when the distance of electrodes was shorter than 2cm

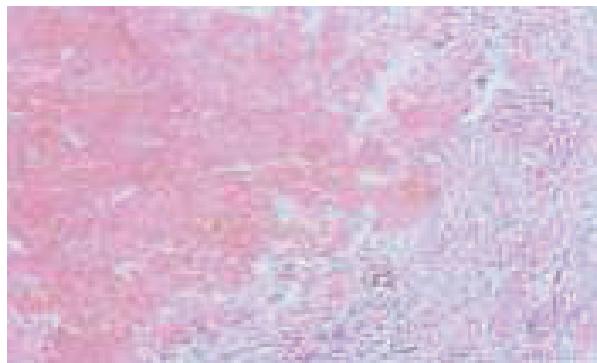


Figure 21. No cancer cells remained when the distance of electrodes is shorter than 2cm

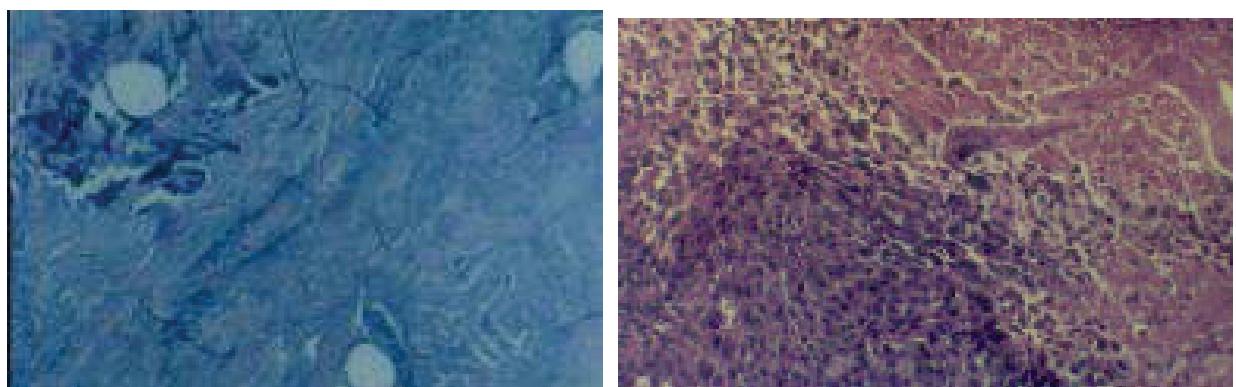


Figure 22. The distance of electrodes is over 3cm. Cancer cells can be found in the remaining area

(3) Requirement of electric current, voltage and electric quantity

Voltage usually used is 8~12 V and electric current is in a range of 80~180 mA. Electric quantity is determined by tumor size, usually 100 coulombs per 1.0 cm diameter of tumor mass.

(4) Duration of treatment

The concept of increasing electric current to high level in order to shorten treating time is wrong. That is because the action of EChT is electrolysis which needs time to perform the action. According to animal experiment, 4 V voltage and 20 mA is enough to have killing effect.

To improve the effectiveness of EChT for treating malignant tumors, following measures are recommended:

(A) For patients with advanced tumor who can not be treated with other therapies, EChT might relieve their sufferings and their life quality could be improved;

(B) For large tumor mass, more electrodes should be needed. If short circuit does not occur, the distance between electrodes could be reduced to 1.0cm in order to increase killing effect

(C) EChT might be combined with radio-chemotherapy, because EChT could make tumor cells more sensitive to radio-chemotherapy.

Positively charged anti-tumor agents, such as adriamycin and bleomycin, could be injected into tumor and moved toward cathode area to kill tumor cells.

(D) Chinese herbs could improve immune system and inhibit growth of tumors, and might be a supplementary treatment to be combined with EChT.

The future of EChT method

In 1987, Professor BJ Nordenström was invited to come to Beijing giving lectures on BCEC theory and demonstrated the use of EChT on malignant tumor. Following three years of animal and clinical practice in China, good therapeutic effectiveness has been achieved. It was approved as a new therapeutic method to be used and spread clinically by the Ministry of Public Health of China.

Over ten thousand cases of various kinds of tumors have been treated with EChT in China within nearly 20 years. It could be used not only for malignant tumors, but also for some benign tumors, such as venous malformations with excellent effectiveness.

The effectiveness of treating benign tumors is even admirable. EChT might be the best method, much better than surgical operation, to treat venous malformations with no bleeding, no scars left and no harm to the appearance and function. EChT was applied on breast hypotrophy and endometriosis in abdominal wall and satisfactory result has been achieved.

Typical cases



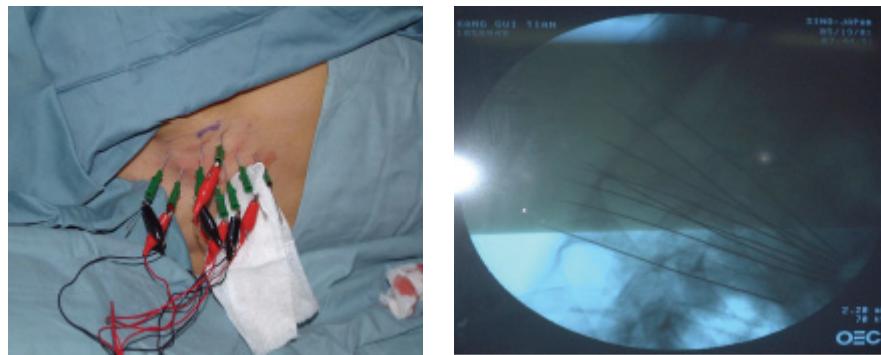
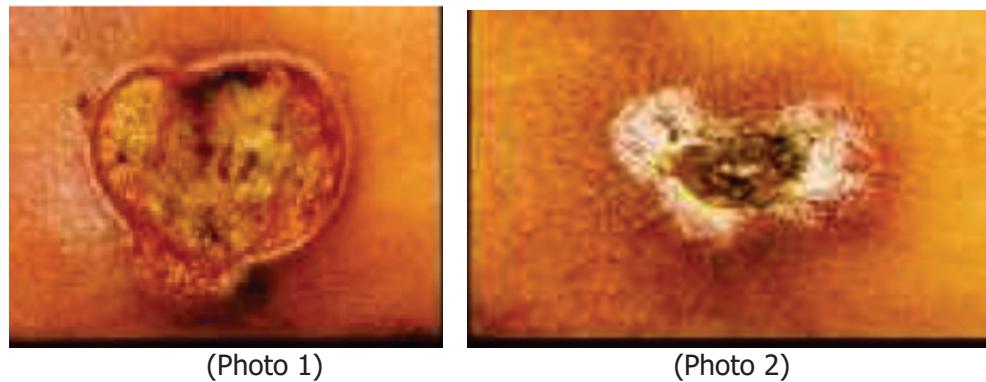


Figure 23. Right lung cancer. X-Ray film before EChT and during EChT



(Photo 1)

(Photo 2)

(Photo 3)

Figure 24. Male, 42y. Cancerous ulcer in right thigh. 5.5x8.0cm. (Photo 1). After 2 times EChT (Photo 2). No recurrence through 6 years following up (Photo 3)



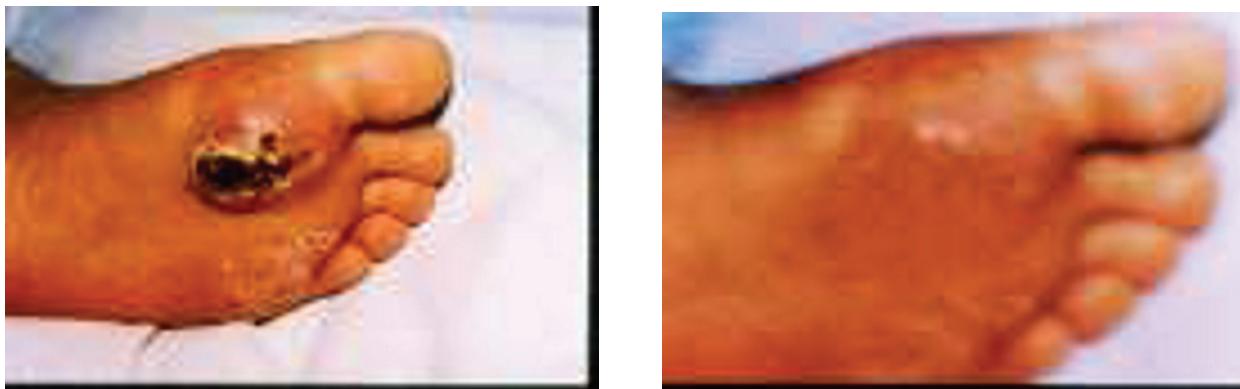


Figure 25. Male, 34y. Melanoma in left foot. Recurred after surgical resected. The wound didn't heal up and the tumor grew to 4.5X5.0 cm. The wound healed 7 weeks after EChT and no recurrence developed through 4 years following up



M.30ys. Right upper limb soft tissue sarcoma recurred after 2 times surgery combining pulmonary metastasis, the tumor size: 13X21cm. Before and during EChT



Figure 27. Tumor turned necrosis and fell off 5 days after EChT. The wound was healed 6 weeks there after. He died of lung metastasis after following up 20 months



Figure 28. Male, 67y. Squamous cell carcinoma of low lip, 2.0x3.5cm. During EChT



Figure 29. The tumor became necrosis and formed a scar after EChT. The photo showed a good figure of the patient 12 months after EChT



Figure 30. M,67y. Lower lip cancer of squamous epithelium, recurred after surgical resection, 2.0X3.5cm. Before and 1 year after EChT



Figure 31. F. 52y. Local recurrence after resection of right mammary cancer. Carcinoma ulcer grew to 12'10cm



(photo 1)



(photo 2)

Figure 32. The tumor necrosed and surface of wound obviously reduced 7 weeks after EChT (photo 1). The wound healed completely 9 weeks after EChT (Photo 2). (photo 1) (Photo 2)



Figure 33. Breast cancer during EChT and 6 months after EChT

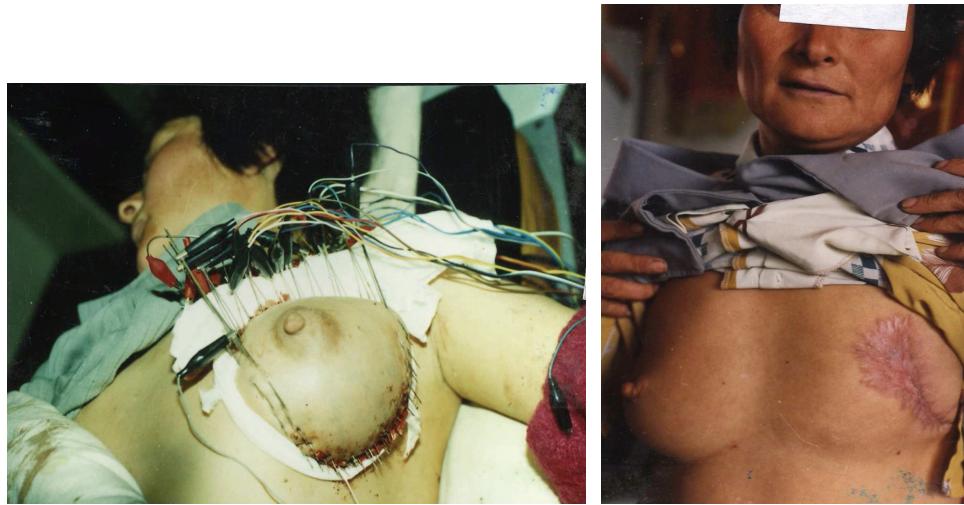


Figure 34. Breast cancer during EChT and 6 months after EChT



Figure 35. M.4y. Hemangioma in right forehead. Operation failed due to uncontrolled bleeding. The diameter was 7.8X9cm



Figure 36. The tumor disappeared and no recurrence developed after 3 years after EChT



(photo 1)



(Photo 2)

Figure 37. M.32y. Huge venous malformations in maxillofacial region. Many therapies had been tried but all failed (photo 1). Photo 2 showed 1.5 years after EChT

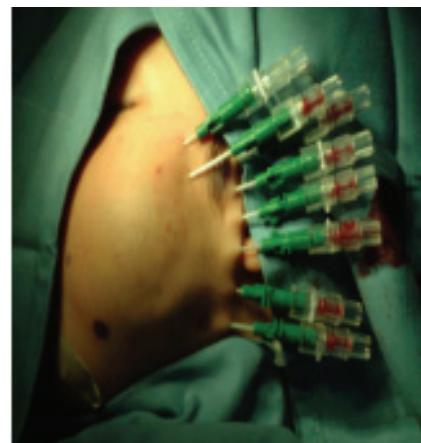


Figure 38. F.2y. Venous malformation in left maxillofacial region before and during EChT

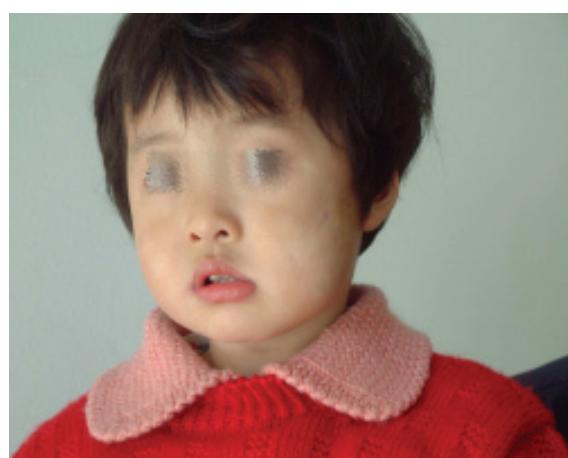


Figure 39. 2 years after EChT



Figure 40. M.32y. Huge hemangioma in tongue. The tongue drop out of mouth and had a malfunction

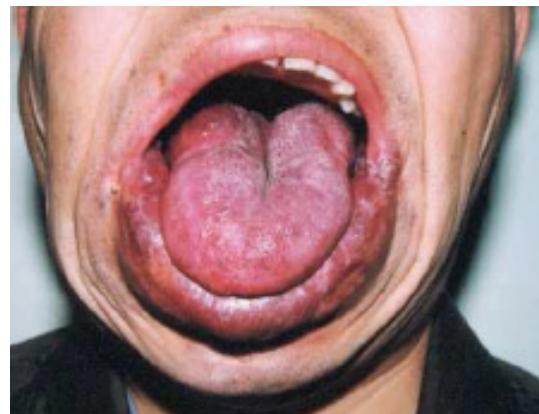


Figure 41. 1 year after EChT. Well function of tongue recovered



Figure 42. F.16y. Multiple hemangiomas in right maxillofacial region tongue & lips. Speaking and foodintake were hindered. No recurrence for 3.5 years follow up after EChT. The well function of tongue and feature recovered



Figure 43. F, 20ys. Hemangioma of tongue before and after EChT



Figure 44. F, 21ys. Maxillofacial & tongue venous malformation



Figure 45. One year after EChT



Figure 46. F.5ys. Up lip venous malformations reccurred after surgical resection. The photos show the patients' appearance before and after EChT



Figure 47. 7 years old girl with big vascular malformation of neck

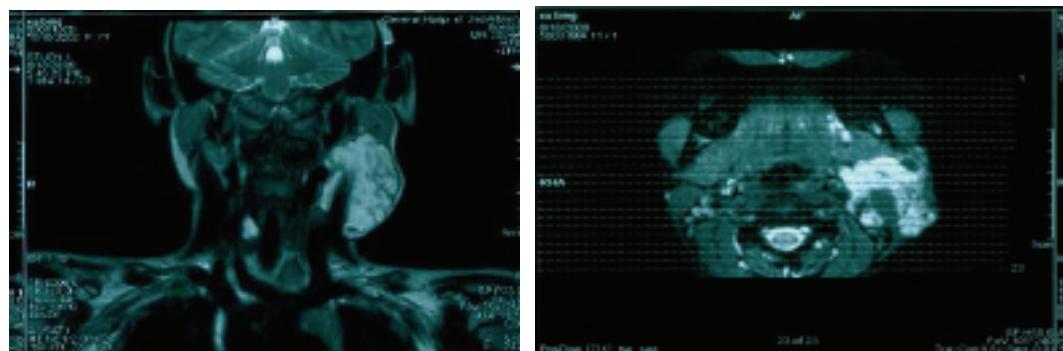


Figure 48. The same patient's MRI before treatment





Figure 49. The same patient's appearance and MRI after EChT



Figure 50. M, 20ys. Severe maxillofacial vascular malformations before EChT

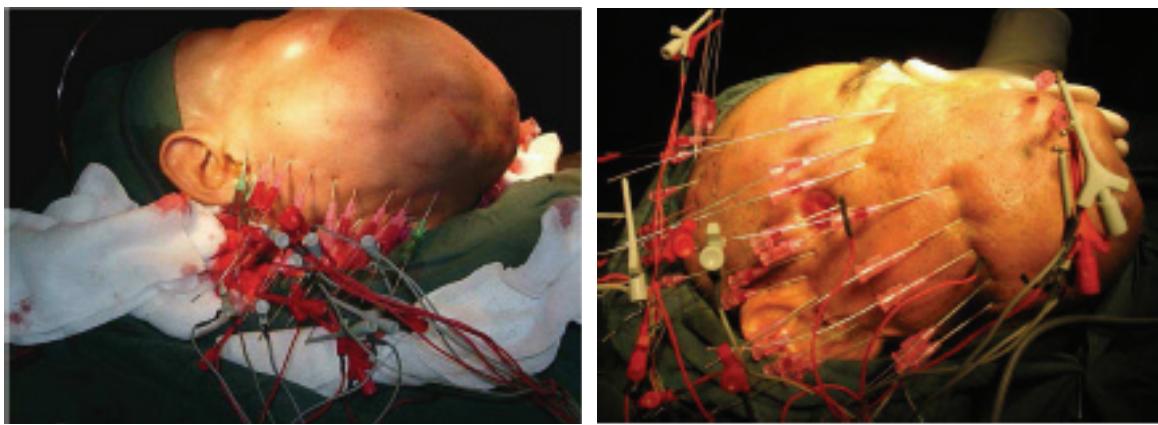


Figure 51. During EChT



Figure 52. 1 year after 3 times EChT 3 times EChT and plastic surgery