1. History of Cryosurgery

Kecheng Xu

Abstract

- Cryosurgery is an old as well as new technique, and has gone through a long-term process of development. The history of “modern” cryosurgery is relatively short and is closely intertwined with developments in low-temperature physics, engineering, and instrumentation that were made during the last century.
- The cryosurgical probes developed in the 1960s allow precise application of cryosurgical treatment deep in the body. This unique ability makes cryosurgery very promising and has resulted in the expansion of the method during this era. Cryosurgery had mainly been applied to uterine tumors and neurologic, orthopedic, and skin diseases.
- From the end of the 20th century, the development of imaging techniques and new freezing equipment has culminated in the creation of modern cryosurgery. The liquid nitrogen operative system and the argon–helium surgical system represent two important stages of modern cryosurgery.
- Now cryosurgery has been successfully used for treatment of a variety of tumors, which include benign and malignant neoplasms of the prostate, lung, liver, pancreas, kidney, breast, uterus, ovary, bone, and soft tissue.

Introduction

Cryosurgery, also referred to as cryotherapy or cryoablative, employs very low temperatures to destroy diseased tissues, and has gone through a long-term process of development (Table 1.1). It is an old technique, because the use of cold for therapeutic effect has been known since ancient history, and
Table 1.1. History of cryosurgery.

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<tr>
<th>Time (years)</th>
<th>Inventor</th>
<th>Cryogens</th>
<th>Application</th>
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<tr>
<td>3500 years</td>
<td>Old Greece</td>
<td>Ice</td>
<td>Treatment of infected wounds</td>
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<td>ago</td>
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<td>Anesthesia</td>
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<td>11th century</td>
<td>Avicenne</td>
<td>Ice</td>
<td>Anesthesia</td>
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<td>1650</td>
<td>Wherry</td>
<td>Ice</td>
<td>Treatment of gout</td>
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<tr>
<td>1845</td>
<td>Faraday M.</td>
<td>Ice and salt water</td>
<td>Freezing tumors</td>
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<tr>
<td>1851</td>
<td>Arnott</td>
<td>Mixture of salt and</td>
<td>Freezing advanced cancers</td>
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<td></td>
<td></td>
<td>crushed ice</td>
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<td>1877</td>
<td>Caillete, France;</td>
<td>Liquid oxygen and</td>
<td>Making low-temperature</td>
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<td></td>
<td>Pietet, Switzerland</td>
<td>nitrogen</td>
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<td>1892</td>
<td>Dewar, UK</td>
<td>Development of the</td>
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<td>first vacuum flask</td>
<td>for facilitated storage and handling of liquefied gases</td>
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<td>1899</td>
<td>Campbell White</td>
<td>First to use</td>
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<td>refrigerants for</td>
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<td>medical practice</td>
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<td>1895</td>
<td>Linde, Germany:</td>
<td>Use of the Joule–Thomson</td>
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<td></td>
<td>Hampson, UK</td>
<td>effect to produce</td>
<td>continuously operating air liquefiers</td>
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<td>1907</td>
<td>Whitehouse</td>
<td>Use of liquid air for epitheliomata</td>
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<td>1907</td>
<td>Pussey William</td>
<td>Solid carbon dioxide</td>
<td>Establishment of cryotherapy</td>
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<tr>
<td>1911</td>
<td>Hall-Edwards</td>
<td>Described carbon dioxide collection model</td>
<td></td>
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<tr>
<td>1940s</td>
<td>Kapitsa, Collins</td>
<td>Liquid hydrogen and</td>
<td>Making liquid nitrogen</td>
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<td></td>
<td></td>
<td>nitrogen</td>
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<tr>
<td>1945</td>
<td>Jarnott</td>
<td>Low temperature</td>
<td>Treatment of tumors</td>
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<td>1950</td>
<td>Allington</td>
<td>Liquid nitrogen</td>
<td>Use of treatment in dermatology and gynecology</td>
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<td>1959</td>
<td></td>
<td>Mixture of ethanol</td>
<td>Cryosurgery</td>
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<td>1961</td>
<td>Cooper, USA</td>
<td>Liquid nitrogen</td>
<td>Treatment of diseases of central nervous system</td>
</tr>
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(Continued)
Table 1.1.  (Continued)

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<thead>
<tr>
<th>Time (years)</th>
<th>Inventor</th>
<th>Cryogens</th>
<th>Application</th>
</tr>
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<tbody>
<tr>
<td>1967</td>
<td>Amoils</td>
<td>Liquid nitrogen probe</td>
<td>Cryoextraction</td>
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<tr>
<td>1968</td>
<td></td>
<td>Liquid nitrogen</td>
<td>Treatment of prostate cancer and liver cancer</td>
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<td>1976</td>
<td>Wright</td>
<td>Nitrous oxide cryo-apparent</td>
<td>Treatment of benign prostate hyperplasia</td>
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<tr>
<td>1985</td>
<td>Zacarian</td>
<td>Developing copper probe</td>
<td>Treatment of deep lesions</td>
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<td>1990s</td>
<td>USA, China</td>
<td>Liquid nitrogen</td>
<td>Treatment of tumors of prostate, liver and kidney</td>
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<tr>
<td>1998</td>
<td>USA</td>
<td>Argon-based cryosurgical system</td>
<td>Treatment of prostate cancer and liver cancer approved by FDA, USA</td>
</tr>
<tr>
<td>After 2000</td>
<td>USA, China</td>
<td>Argon-based cryosurgical system</td>
<td>Treatment of tumors of liver, lung, kidney and pancreas</td>
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</table>

it is a new option as well, because the practical use of cold for therapeutic purposes was carried out during the last century [Zonnevylle, 1981; Gage, 1998]. Today’s cryosurgery is experiencing greater international attention and dissemination, and has become an important clinical technique mainly for the treatment of malignant and benign tumors [Gage, 1998].

Ancient times: treatment of infected wounds

The ancient Egyptians, and later Hippocrates, were aware of the analgesic and anti-inflammatory properties of cold, and with it they treated infection lesions of the chest, fractures of the skull, and various battle injuries (Figure 1.1) [Zonnevylle, 1981].

Mid–19th century: use of a mixture of salt and ice

James Arnott [1851] (1797–1883) (Figure 1.2), an English physician, was the first person to use extreme cold locally for the destruction of tissue. In
1845, he described the use of iced-salt solutions (about \(-20 ^\circ C\)) to freeze advanced cancers in accessible sites, resulting in reduction in tumor volume and amelioration of pain and local hemorrhage [Bird, 1949]. The cancers treated by Arnott using the freezing technique included breast cancer, uterine cancer, and some skin cancers. Although palliation was the main aim, he recognized the potential of cold for curing cancer. He advocated cold treatment for acne, neuralgia, and headaches, achieving a temperature of \(-24 ^\circ C\). In addition, he recognized the analgesic “benumbing” effect of cold, recommending the use of cold to anesthetize skin before operation. His contribution to the development of cryosurgery was crucial. A piece of equipment designed by Arnott consisted of a waterproof cushion applied to
the skin, two long flexible tubes to convey water to and from the affected part, a reservoir for the ice/water mixture, and a sump. The equipment was exhibited at the Great Exhibition of London in 1851 and Arnott won a prize for his effort [Bird and Arnott, 1949].

Late 19th century: use of liquid air

In the late 1800s, a new type of freezing agent, liquefying gases, had been developed along with tremendous scientific advances. On Christmas Eve of 1877, Cailletet [1878] demonstrated at the French Academy of Science that oxygen and carbon monoxide could be liquefied under high pressure. In the following year, 1878, Pictet [1878] also demonstrated the liquefaction of oxygen, but used a mechanical refrigeration cascade. In 1895, it was the first time that Carl von Linde succeeded in liquefying air by compressing it and then letting it expand rapidly, thereby cooling it, and so that produced commercial liquid air, which promoted its widespread use.

Campbell White [1899, 1901], a physician of New York, was the first person to employ refrigerants for clinical use. He reported the use of liquid air for the treatment of different diseases, including lupus...
erythematous, herpes zoster, chancroid, nevi, warts, varicose leg ulcers, carbuncles, and epitheliomas, in 1899. He showed the efficacy of liquid air in the treatment of carcinoma, and enthusiastically stated: “I can truly say today that I believe that epithelioma, treated early in its existence by liquid air, will always be cured.”

Whitehouse [1907] reviewed the effects of liquid air on normal skin, and stated that liquid air “outranks some of the remedies on which we have placed great reliance.” He demonstrated that cryogen was especially useful for epitheliomata, lupus erythematosus, and vascular nevi. For the recurrence of epithelioma after radiotherapy, he showed liquid air to be more successful than repeat radiotherapy. During this period, there were other scholars interested in the clinical use of cryogen as well. Bowen and Towle [1907] reported the successful use of liquid air for vascular lesions in 1907.

**Early 20th century: carbonic acid snow**

The debate on the best cryogen to use persisted during the early 20th century [Bracco, 1990]. In 1910, Gold [1910] showed that liquid air was far preferable. In 1929, Irvine and Turnacliffe [1929] similarly favored liquid air and oxygen over carbon dioxide snow, and reported liquid air treatment of seborrheic keratoses, senile keratoses, lichen simplex, poison ivy dermatitis, and herpes zoster. They found liquid oxygen very useful for warts, declaring that “it offers a practically sure, quick and painless method for removal of all types of warts, including the plantar type.”

However, an important fact is that liquid air was very difficult to obtain, limiting its wide use. In the 1920s, carbon dioxide snow (or carbonic acid snow) had been developed. The freezing agent was easy to obtain. The liquid carbon dioxide gas was supplied in steel cylinders under pressure. When the gas was allowed to escape, rapid expansion caused a fall in temperature (the Joule–Thompson effect) and a fine snow was formed. The snow was easily compressed into various shapes, known as pencils, suitable for different treatments.

In 1935, William Pusey [1935], a doctor of Chicago, first reported the use of carbon dioxide snow for the treatment of a large black hairy nevus on a young girl’s face, successfully resulting in depigmentation of the lesion. This was one of the first demonstrations of the extraordinary
sensitivity of melanocytes to cold. After successfully treating other nevi, warts, and lupus erythematosus, Pusey stated regarding the carbon dioxide snow: “We have found a destructive application whose action can be accurately gauged and is therefore controllable.” He recognized the low scarring potential of cryosurgery and suggested that this was the result of regeneration of residual epidermal cells rather than being due to collagen’s resistance to cold.

Hall-Edwards [1913] of Birmingham, UK first reported his collector and compressor of carbon dioxide in 1911 (Figure 1.3). In his monograph,
written later in 1913, he detailed the use of carbon dioxide for the treat-
ment of many conditions, particularly rodent ulcers. He showed the place
of cryosurgery in relation to x-ray use. His study was a great contribution
to cryosurgery. At the same time, Cranston-Low [1911], a physician in the
Edinburgh skin department, also reported the use of carbon dioxide snow,
showing that “thrombosis, direct injury to tissues, and the inflammatory
exudates probably all act together” to produce the effects of freezing.

In the following years, carbon dioxide snow was very successfully
used for a wide variety of benign skin conditions and remained popular
until the 1960s. De Quervain reported the successful use of carbonic snow
for bladder papillomas and bladder cancers in 1917 [Bracco, 1990].

During that period, several devices for the use of carbon dioxide snow
were developed. For example, Campbell White designed a roller for the
treatment of erysipelas [Rubinsky, 2000]. The great advantage of liquid
air was that it was easy to obtain the lower temperatures, allowing tumors
to be treated, but a disadvantage was the difficulty in obtaining and trans-
porting it. Sir James Dewar solved the problems of transportation and
storage by inventing a flask made up of two walls of glass with a vacuum
between [Gage, 1998; Rubinsky, 2000]. Even today, the containers used
for refrigerants have much the same design.

Mid–20th century: use of liquid nitrogen

Up to the mid–20th century, liquid nitrogen was used for clinical treat-
ment [Grimmett, 1961]. Allington [1950] was the first to use liquid
nitrogen; he discovered that its properties were very similar to those of
liquid air and oxygen. He used a cotton swab for treating various benign
lesions. But further study showed that the option was insufficient for
tumor treatment due to poor heat transfer between swab and skin.

The use of liquid nitrogen constituted the beginning of modern
cryosurgery. Irving S. Cooper [1963], a neurologist at New York’s Saint
Barnabas Hospital, was a pioneer in cryosurgery using liquid nitrogen and
made a great contribution to this field. He designed a liquid nitrogen
probe that was capable of achieving temperatures up to –196°C. Using the
probe, he treated Parkinson’s disease and other movement disorders by
freezing the thalamus. Some previously inoperable brain tumors met with
improvement by his therapy. An example was his treatment for nine-year-old Steve Schiavo, who suffered from dystonia, a crippling condition caused by a brain tumor and characterized by tremors, muscle deformities, and loss of muscle control. The patient could no longer walk, and his arms had constant tremors. Using X-rays, Cooper accurately positioned the cryosurgical probe, freezing the tumor to \(-10^\circ\text{C}\), and performed brain cryosurgery on the boy successfully. Cooper’s work led to an explosion of interest in liquid nitrogen and its eventual acceptance as a standard treatment in many specialties [Das et al., 1998].

It is necessary to point out Zacarian’s contribution to freezing equipment and clinical cryosurgery. Zacarian [1985] developed two kinds of equipment: one was a hand-held device which allowed one-handed operation with trigger-type control and permitted variations in the spray diameter at interchangeable tips; the other was a copper probe that allowed tissue freezing to depths of up to 7 mm. He published many papers on cryosurgical science and practice which promoted the development of office-based practice. Because of Zacarian’s donation, the Oxford Dermatology Department became the focus of cryosurgical research in Britain in the 1970s.

In 1967, Amoils [1967] reported that he had performed cataract extraction called cryoextraction successfully using a closed-loop Joule–Thomson cryosurgical probe. According to his report, the cryo-probe acted by freezing to the capsule at the point of application and freezing the adjacent lens matter into an “ice ball” for about 3 mm around the tip of the probe. This ice ball became, so to speak, an extension of the instrument, and traction acted as if it were coming from within the lens rather than via the capsule. Hence, the capsule breakage rate was greatly reduced to approximately half that of the forces or erysiphake [Amoils and Thomas, 1971]. The only operative complications were accidental touching and sticking of the probe to the cornea or iris, which was easily separated by heating the probe. The author suggested that cryoextraction was a safe and easy method for removing cataracts, especially mature ones, and could to a great extent replace the forceps or erysiphake [Amoils and Thomas, 1971]. This system is still widely used in gynecology and ophthalmology. But cooling is slow and temperatures are not low enough to ablate tumor.
The great advances in knowledge of the biological effects on freezing have been made in the past half-century. Almost all researches have concerned the effects of liquid nitrogen. The development of temperature probes that can be inserted into skin has allowed measurement of tissue temperatures during freezing. An accurate picture of the shape and depth of ice ball formation with different lengths of freezing has been built up, allowing development of guidelines for freezing times [Kuflik and Gage, 1990].

Rand et al. [1969] performed a transphenoidal hypophysectomy with liquid nitrogen. Cryohypophysectomy involved placement of a cryoprobe into the anterior lobe of the pituitary gland via the nasal vault and sphenoid sinus under x-ray control. The patient was awake under local anesthesia. In 13 patients with acromegaly and elevated plasma growth hormone levels, remission was achieved. No optic nerve or extraocular motor nerve palsies resulted and there was no mortality. The author pointed out that cryosurgery could be repeated if growth hormone levels were lowered insufficiently to give the desired results.

Gage [1969] treated 50 patients of oral and oropharyngeal cancers and achieved survival benefit comparable to that of excision. Chandler treated 50 patients with malignant tumor of the head and neck, 32 of whom were treated for cure. William G. Cahan [1967] of the Memorial Sloan-Kettering Cancer Center, USA, pointed out that the main advantage of the cryoprobe designed by him was that it reduced bleeding in the area of surgery. Cahan [1967] used cryosurgery to treat a cancer of the uterine cervix painlessly and bloodlessly; the procedure was later found to be more effective for the precancerous lesions of the cervix. Cahan also reduced a large tongue cancer by cryosurgery, and then removed the shrunken lesion using regular surgical techniques. Pearson [1968] showed his experience with cryotherapy of head and neck tumors.

Also, Leo Schwartz, a New York surgeon, who was an ear–nose–throat specialist, practised cryosurgical medicine in Manhattan, during a period of more than 40 years, using liquid nitrogen to remove small tumors of the larynx that were not cancerous. University of Michigan doctors Walter Work and Mansfield F. W. Smith used cryosurgery to remove noncancerous blood vessel tumors in the nose called angiofibromas, which can cause massive nosebleeds. They used liquid nitrogen to remove the tumors with no significant blood loss [Rubinsky, 2000].
Though experience with cold injury and therapy was described in ancient manuscripts and in experiments with frostbite in the 19th century, most current knowledge is based on investigations that began in the 1940s, initially with frostbite and then with the use of freezing techniques to preserve cells or produce local lesions for physiological investigations. Nevertheless, cryosurgery has not been as popular as expected. One of the reasons, presumably, is no proper means of monitoring the extent and process of freezing–thawing. Another reason may be no breakthrough of equipment for cryosurgery [Harada et al., 2005].

Late 20th century to the present: imaging-guided cryosurgery

Since the late 20th century, cryosurgery has undergone great development. This has resulted from a more in-depth survey of three important topics in cryosurgery: (a) the biochemical and biophysical mechanisms of tissue destruction during cryosurgery; (b) new freezing equipment; (c) monitoring and imaging techniques for cryosurgery [Rubinsky, 2000; Harada et al., 2005].

Regarding the freezing equipment, the liquid nitrogen operative system and the argon–helium operative system are the representatives of two important stages of modern cryosurgery. In the mid-1990s, the next-generation multiprobe high-pressure argon–helium system was introduced [Almeido Gongalves, 1986; Hunsaker et al., 1985; Meijer et al., 1999]. This generation of cryosurgery machine utilizes the Joule–Thomson effect, in which different gases undergo unique temperature changes when depressurized, according to unique gas coefficients. The properties of argon make it useful for cooling to below –180°C, whereas helium is ideal for thawing and rewarming. The use of gas allows rapid transition from freezing to defrosting, which facilitates tighter control as well as expedient of the procedure. Further improvements in technology include a significant reduction in the probe diameter. Ultrathin probes with sharp tips now allow direct percutaneous probe placement.

Another technological advance which has caused renewed interest in cryosurgery is the development of intraoperative ultrasound to monitor the therapeutic process. The manner of use is to place the probe at the
desired location in the diseased tissue under ultrasound, CT, or MRI guidance. If required by the size or location of the tumor, multiple probes can be inserted and cooled to \(-160^\circ\text{C}\) simultaneously [Harada et al., 2005].

Clinical applications of cryosurgery have become common in the past 10 years. The cases selected for cryosurgery are generally those for which no conventional treatment is possible. However, especially in prostatic cancer, the cryosurgical morbidity is very low and the results of therapy are sufficiently good in the short term to merit consideration for use in earlier stages of the disease. Diseases which are adaptable to cryosurgery include not only prostatic cancer and liver tumors, but also diverse tumors in other sites, such as the lung, brain, breast, bone, pancreas, kidney, and uterus [Xu et al., 2007].

During that period, large amounts of experimental and clinical researches have emerged. More than 16 international conferences of cryosurgery have been convened by the International Society of Cryosurgery. The magazine Cryobiology has published 60 volumes. Approximately 20,000 papers with relevant information on cryosurgery for cancer have appeared in a variety of academic magazines, according to an online PubMed search using the keywords “cryosurgery,” “cryoablation,” “cryotherapy,” and “cancer.”

The monograph Basics of Cryosurgery, edited by Nikolai Korpan in 2001, has comprehensively described the principle and clinical application of cryosurgery in a variety of tumors. In it, Dr. Korpan presents some new opinions; for example, he states: “All patients with pancreatic cancer have responded well to cryosurgery” and “There were no surgical complications or mortality directly associated with the cryosurgery” [Gonder et al., 1966]. He has also edited Cryoscience and Cryomedicine (2006) and Cryoscience and Cryomedicine (2009). Other monographs include Clinical Application of Cryobiology, edited by Barry J. Fuller and B. W. W. Grout in 1991; Cutaneous Cryosurgery, edited by Rodney Dawber, Arthur Jackson, and Graham Colver in 2005; Urologic Cryoablation, edited by D. B. Rukstalis and A. Katz in 2007; and Step by Step Colposcopy Cryosurgery and LEEP, edited by B. Shakuntala Baliga in 2009.

In Asia, cryosurgery as a practical technique has been developed. The monograph Percutaneous Cryotherapy of Renal Cell Carcinoma Under an Open MRI System, edited by J. Harada, K. Miyasaka, and S. Sumida of Japan, was published in 2005. This is a pilot work which describes the
advanced technique of cryosurgery using MR imaging guidance. Sumida and his colleagues founded the Japanese Society for Low Temperature Medicine in 1974, which has moderated the annual academic conference for 37 years up to now. In September 2010, the Preparation Committee of the Asian Society of Cryosurgery was founded in Guangzhou, China, with the members including surgeons and physicians who are at work on cryosurgery from Asian countries and regions, including China, Hong Kong, Indonesia, Japan, and South Korea.

In China, cryosurgery for cancer has been paid great and continued attention. In the 1990s, Zhou used open cryosurgery (liquid nitrogen) for the treatment of a large number of hepatocellular carcinomas, with results comparable to that of operative resection [Zhou et al., 1988; Zhou, 1992]. Since the early 21st century, cryosurgery using the argon-based cryosurgical system has been applied at more than 100 hospitals or medical centers in China. More than 20,000 patients with malignant and benign tumors have received cryosurgery. It is especially noted that most cases of cryosurgery performed in China used the percutaneous approach. China has become one of the countries where cryosurgery has been popularly used. In 2007, the 14th International Conference of Cryosurgery was held in Beijing, China. In the same year, Cryosurgery for Cancer (in Chinese), edited by Dr. Kecheng Xu and Dr. Lizhi Niu, was published by the Shanghai Science-Education Publishing House. This is the first monograph on the field of cryosurgery in China [Xu et al., 2007].

Many scholars have made great, historic contributions to the development of cryosurgery for tumors in recent years. Here we are honored to list most of these scholars (according to incomplete data).

**Prostate cancer cryosurgery**

In the 1960s, Gonder [1966; Soanes and Gonder, 1968] was the first to report prostate cryosurgery using a single transurethral liquid nitrogen probe to treat bladder outlet obstruction caused by benign prostatic hyperplasia and prostate cancer. In 1972, Flocks et al. [1972] modified the technique by using an open transperineal approach with visual control of the cryoablation. In 1974, Megalli et al. [1974] was the first to employ a closed perineal approach using a single 18 F liquid nitrogen probe. Onik et al. [1991] revived interest
in prostate cryosurgery in the early 1990s, combining endourologic percutaneous techniques with the introduction of real-time transrectal ultrasound (TRUS). In addition, improvement of thermosensors by Steed et al. [1997] in the 1990s allowed precise monitoring of the ice ball. Introduction of a warming catheter for urethral mucosa protection resulted in a significant reduction in sloughing and incontinence rates, thereby reducing morbidity and improving success rates. In the following years, Bahn et al. [2003] and Cohen [2004] in the USA made significant contributions regarding technical improvement and increase in the efficacy of cryosurgery for prostate cancer.

**Liver cryosurgery**

*Open cryosurgery for liver cancer*

Heard [1955] was one of the first to describe the morphological appearance of the liver subjected to slow cooling. In the same year, Serra and Brunschwig [1955] reported numerous experimental and clinical studies investigating the effects of freezing on the hepatic tissue. The first use of cryosurgery for ablation of liver cancer was described by Cooper in 1963 [Cooper, 1963]. In 1970, Stucke and Hirte [1970] of Germany published a clinical report on cryosurgery for liver cancer. Russian Shalimov also described cryoeffect in liver surgery in 1979 [Shalimov et al., 1979]. Zhou et al. [1988] of Shanghai, China reported experimental and clinical study in the same year. Since then, Zhou and his colleagues [Zhou, 1992; Zhou et al., 1998, 2002] have reported largest series of open cryosurgery for the treatment of hepatocellular carcinoma. During the past more than 10 years, Gage (USA) [1982], Onik (USA) [1984], Ross (USA) [1993], Hobbs (UK) [1993], Weaver (USA) [1995], Korpan (Austria) [1997], Rivoire (France) [1997], Seifert et al. (Germany) [2002], Haddad (USA) [1998], Mala et al. (Norway) [2004], and Adam et al. (France) [1997] have published papers on open hepatic cryosurgery.

**Laparoscopic cryosurgery for liver cancer**

In 1997, Tandan et al. [1997] of Canada first made an experimental observation of laparoscopic cryosurgery for hepatic tumors, and presented a
report on a patient who underwent this therapy. Then, Iannitti and his colleagues (USA) [1998], Lezoche and his assistants (Italy) [1998], and Shimonov (Israel) [2002] reported their results of laparoscopic cryosurgery for the treatment of liver cancer.

**Percutaneous cryosurgery for liver cancer**


**Lung cryosurgery**

**Endobronchial cryosurgery for lung cancer**

The main contributors to this therapy are Maiwand and Asimakopoulos of the UK, who reported endobronchial cryosurgery for more than 500 patients with lung cancer during a nine-year-period in 2003 and 2004 [Maiwand *et al.*, 2004].

**Open cryosurgery for lung cancer**

Ping Liu [1985, 1991a,b] from China edited a monograph entitled *Pulmonary Cryosurgery*, in which he describes the surgical results under open thoracotomy using a lung freeze-fixation instrument for 80 patients with pulmonary tumor. The five-year survival was 24.3% in 37 cases of primary pulmonary cancer. The cryosurgery for pulmonary carcinoma by Liu could have been the first attempt in the world. Maiwand *et al.* (UK) [2004] published the first and only report on direct cryosurgery for lung cancer.

**Percutaneous cryosurgery for lung cancer**

Wang (China) [2004], Kawamura (Japan) [2006], and Niu (China) [Niu *et al.*, 2007] sequentially reported their experience of percutaneous
cryosurgery for lung cancer. In Niu’s report, percutaneous cryosurgery for centrally located lung cancer is encouraging [Niu et al., 2007].

**Cryosurgery for pancreatic cancer**

Kovach et al. (USA) [2002] reported the use of open cryosurgery for the treatment of pancreatic cancer in 2002. Korpan (Austria) pointed out the effectiveness and safety of cryosurgery for pancreatic cancer [2001b]. Xu and Niu (China) [2008b] first used percutaneous cryosurgery to treat locally advanced pancreatic cancer with or without iodine-125 seed implantation.

**Cryosurgery for breast cancer**

In 1997, Staren et al. (USA) [1997] proved feasible and efficacious breast cryosurgery in small and large animal studies, and reported one patient with breast cancer who had successfully undergone the therapy. Ablin [1998] further reported the experience of breast cryoablation in the same year. After this, there are several specialists, such as Pfleiderer (Germany) [2002], Kaufman (USA) [2004], Sabel (USA) [2005], and Littrup (USA) [2005], who showed that percutaneous cryoablation is a feasible and promising treatment protocol.

**Renal cryosurgery**

**Open cryosurgery for renal cancer**

In 1996, Delworth of the USA [1996] performed pioneering work of an open cryoablation for renal cell carcinoma. Two years later, Lugnani (Italy) [1998] reported a similar result. Since then, Rukstalis (USA) [2001], Pantuck (USA) [2002], Khorsandi (USA) [2002], and Badwan (USA) [2008] have reported their experience of open cryosurgery for renal tumors.

**Laparoscopic cryosurgery for renal cancer**

Gills et al. [2003] made a great contribution to laparoscopic cryosurgery for renal tumors. Bishoff (USA) [1999], Nadler (USA) [2003], Janzen
(USA) [2003], and Weld [2007] sequentially reported their experiences in this field.

**Percutaneous cryosurgery for renal cancer**
Renal tumor cryoablation with a percutaneous approach under ultrasound guidance was first described by Uchida (Japan) in 1995. In the following years, Harada (Japan) [2001], Sewell (USA) [2003], Shingleton (USA) [2003], Gore (USA) [2005], and Kodama (Kodama) [2005] also reported the results of percutaneous cryosurgery for the treatment of renal tumors.

**Cryosurgery for uterine fibroids**
The contributors to the development of cryosurgery for uterine fibroids include Zreik (USA) [1998], Duleba (USA) [2003], Cowan (USA) [2004], Dohi (Japan) [2004], Zupi (Italy) [2004], etc.

**Cryosurgery and immunology**
Since the 1980s, Fazio (Italy) [1982], Eastham [1976], Kogel (Germany) [1985], Wang (China) [1989], and Suzuki (Japan) [1995] have attempted to characterize the immunologic changes in patients undergoing cryoablation of cancers. Ablin (USA) [1995] first showed the concept of cryoimmunology in 1995. Fontana (Italy) [1975], Jaeschock (Germany) [1976], Kogel (Germany) [1985], Hoffmann (USA) [2001], and Sabel (USA) [2005] have also done important research in this field.

**Cryosurgery and chemotherapy**
Korpan [2001a], Mir [2002], and Baust [2004] studied the relationship between cryosurgery and chemotherapy.

**Conclusion**
Cryosurgery is a surgical technique that employs freezing to destroy undesirable tissue. First developed in the middle of the 19th century, it has
recently incorporated new imaging technologies and become a fast-growing and minimally invasive surgical technique. It is anticipated that cryosurgery, especially percutaneous cryosurgery, will become a practical and effective modality for treatment of a variety of early and advanced cancers.

References


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