Cryosurgical Equipment: A Critical Review

Daron G. Ferris, MD, and James J. Ho, BSME
Augusta, Georgia

Background. Cryosurgery is frequently used by family physicians to treat benign and premalignant epithelial disease. A professional medical team consisting of a practicing cryotherapist and a mechanical engineer independently critically evaluated the design, function, and performance of selected cryosurgical equipment.
Methods. Qualitative observations and quantitative measurements were performed on seven nitrous oxide cryosurgical units and one liquid nitrogen unit, representing seven manufacturers and distributors. Specific isotherm generation distributions, lateral spread of freeze and refreeze measurements, defrost intervals, recovery zone sizes, relative ease of use, and component characteristics were comparatively assessed.
Results. The in vitro mean lateral spread of freeze distance at 180 seconds varied between 5.8 mm for the Frigitronics CryoPlus and 4.6 mm for the Leisegang LM-900. The mean −20°C isotherm generation time, measured by a thermocouple 3 mm lateral to the cryoprobe tip margin, ranged from 229 seconds for the Wallach WA-1000B to 361 seconds for the Spembly PCG 9R. Defrost times varied between 2 seconds for the Wallach WA-1000B and 320 seconds for the Brymill Mini-Cryogun. Refreeze time was quickest (36 seconds) using the GyneTech GT-1S. The mean in vitro recovery zones varied between 1.6 mm and 2.1 mm.
Conclusions. This evaluation documented both differences and similarities among various cryosurgical units in terms of design, function, and performance. The Wallach, Frigitronics, and GyneTech nitrous oxide cryosurgical units demonstrated the best overall performance.
Key words. Cryosurgery; surgical equipment; equipment design; comparative study. *J Fam Pract 1992; 35:185-193.*

Cryosurgery is a simple, ablative-type surgical technique. The popularity of this procedure can be attributed to several factors: applicability to multiple organ systems, a wide range of disease indications (ie, viral, premalignant, and malignant tissue), rapid procedural times, relatively low cost, office-based suitability, and minimal operative and postoperative complications. Most important, cryosurgery has demonstrated proven effectiveness.[1-2]

Many cryosurgical units are commercially available and no two are identical. Furthermore, the design, function and performance characteristics of cryosurgical units may be variable. Cryosurgical units have not been previously examined from a comparative standpoint. Therefore, the purpose of this study was to critically evaluate commercially available cryosurgical units.

Submitted, revised, February 10, 1992

From the Department of Family Medicine, Medical College of Georgia, Augusta. Requests for reprints should be addressed to Daron G. Ferris, MD, Department of Family Medicine, Medical College of Georgia, Augusta, GA 30912.

ISSN 0094-3509

The Cryosurgical Unit

Principles

The evaluation chiefly emphasized cryosurgical units that used nitrous oxide as the cryogen. These units operate by the Joule-Thomson effect.[3] This method of refrigeration results from the adiabatic principle or the expansion of the gas through a small opening. Pressurized nitrous oxide advances down the narrow cryogun barrel. When it reaches the hollow cryoprobe tip, the gas rapidly expands, lowering it to a temperature below freezing. Although the cryoprobe tip visibly cools with unit activation, the tip must actually be considered a heat sink. As the tip removes heat from the tissue, the tissue gradually cools. The size, material, composition, and temperature of the probe's tip determine its capacity as a heat sink.[3] Other factors, such as tissue moistness, extent of tissue contact, the duration of freeze, and pressure exerted on the probe, affect heat diffusion.

The extent of cryonecrosis is influenced by the speed at which tissue freezes and thaws. A rapid freeze and a slow thaw maximize results.[4] A freeze-thaw-freeze treat-

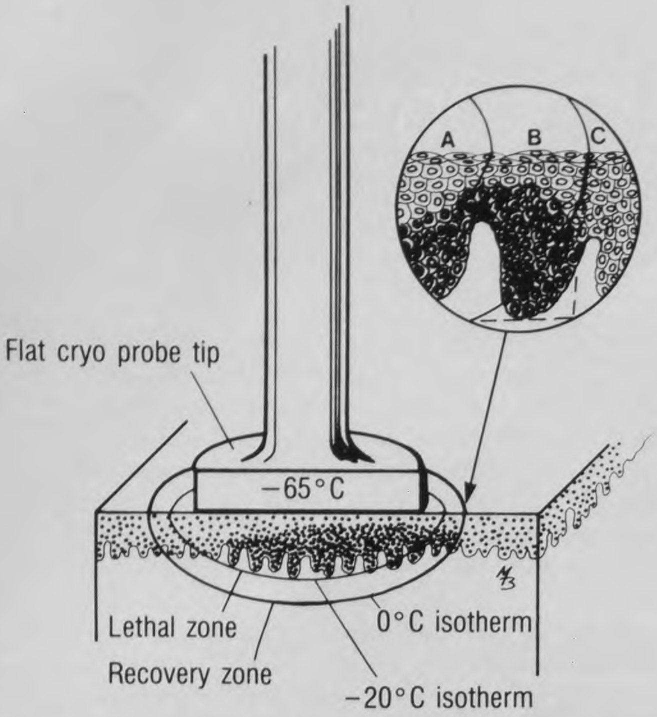

Figure 1. Nitrous oxide cryosurgical iceball indicating the visible ice-tissue interface or 0°C isotherm, the −20° isotherm, and the cryoprobe tip temperature (−65°C). The lethal zone (insert A) represents the iceball volume between the cryoprobe tip margin and the −20°C isotherm. The recovery zone (insert B) represents the iceball area between the −20° isotherm and the 0°C isotherm. Cells located lateral to the −20° isotherm (insert B and C) may remain viable. Abnormal cells in insert C are not frozen.

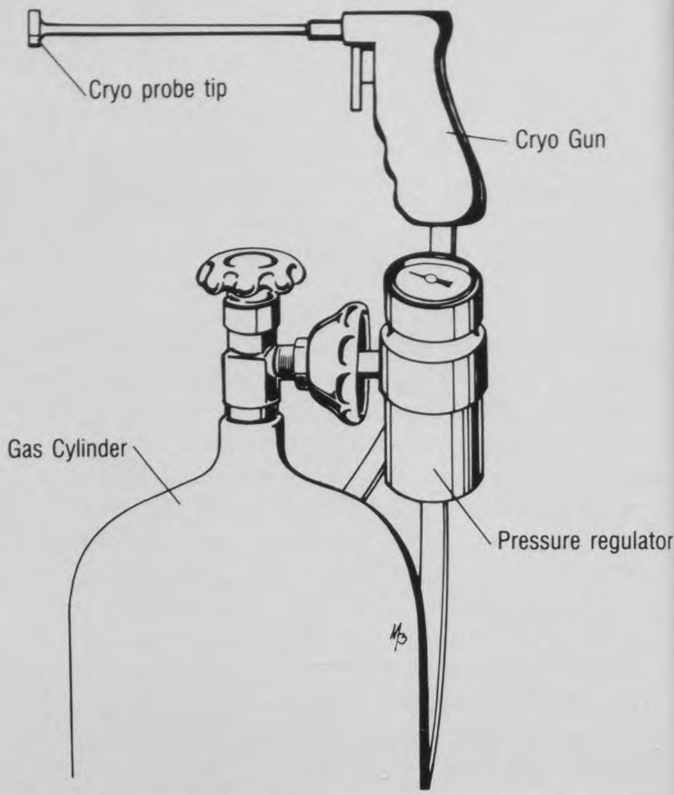

Figure 2. The cryosurgical unit with a gas cylinder, pressure gauge, cryogun, and cryoprobe tip.

ment cycle is also more effective than a single freeze technique for gynecologic procedures.[5]

The temperature of the nitrous oxide cryoprobe tip drops to approximately −65°C to −85°C following unit activation. When the cryosurgical unit is activated and the probe is placed in firm contact with the tissue, an area of frozen tissue or "iceball" may be observed extending radially from the cryoprobe tip. The interface between the iceball and unfrozen tissue represents the 0°C isotherm, which is the line of connected points representing 0°C at the given time (Figure 1). The longer the duration of the freeze, the farther the iceball radiates from the cryoprobe tip margin. The distance between the tip margin and the 0°C isotherm represents the *lateral spread of freeze*. The depth of the 0°C isotherm from the tip indicates the *depth of freeze*. Although variable, the lateral spread of freeze approximates the depth of freeze by a ratio of 1 : 1.3.[6] The depth of freeze is not visually apparent; therefore, to ensure proper depth of tissue destruction, the lateral spread of freeze is commonly used to estimate the definitive treatment margin.

The volume of tissue located between the −20°C isotherm and the probe tip is called the *lethal zone*. Cells within the lethal zone (less than −20°C) undergo cryonecrosis.[7] Those cells situated in the warmer region between the −20°C isotherm and the 0°C isotherm generally survive the freeze. This important region represents the *recovery zone*. The rationale for freezing well past lesion borders is based on this critical thermal characteristic of tissue.

Components

A cryosurgical unit consists of five main components: a nitrous oxide gas cylinder, the cryogen or gas, a pressure gauge, a cryogun with tubing, and assorted cryoprobe tips (Figure 2). Units are usually mounted on a cart to facilitate mobility. Various other accessories are available including tissue temperature monitoring devices or pyrometer thermocouple systems.

The Gas Cylinder

A 20-lb, nonsyphon gas cylinder is recommended for clinical use. The smaller 6-lb "E" cylinders hold less gas and must be refilled more frequently. The efficiency of cryotherapy is dependent on maintaining adequate gas pressure within the cylinder. Internal gas pressure decreases during freezing and must regenerate to 760 psi at room temperature between freezes to maintain adequate pressure. Most units incorporate regulators to reduce or control tip pressures for economy and safety. The regulators provide a constant performance at various cylinder pressure levels.

The Cryogen

The two common cryosurgical methods are dependent on different cryogens, which are the freezing agents. Liquid nitrogen (LN_2) generates low target tissue temperatures because of a boiling point of −195.8°C. The cryogen may be sprayed on tissue, applied with a swab device, or used within an enclosed system.

A container with a pressure-relief mechanism produces constant LN_2 gas evaporation, and requires frequent gas replenishment.

Nitrous oxide, a nonflammable gas with a boiling point of −89.5°C, may be stored in a closed-container system, which prevents continuous gas evaporation. Unlike other procedures in which liquid nitrogen is used, in cryosurgery, the nitrous oxide remains within the probe tip, and the cryogen is not applied directly to the tissue. The duration of freeze necessary to produce effective cryonecrosis may be greater than for LN_2 because of the relatively warmer cryogen.

The Gas Pressure Gauge

All nitrous oxide cryosurgical units feature a gas pressure gauge located between the cylinder and the cryogun. The gauge simply indicates the pressure within the cylinder, either recorded as kg/cm^2 or lbs/in.^{2}, and is divided into three pressure zones. The high zone on the gauge reflects excessive cylinder pressure (a safety hazard) and the middle zone indicates optimal or adequate pressure. Low gas pressure results in inefficient and probable inadequate freezing.

The Cryogun

The cryogun consists of a hand grip or handle, activation trigger(s), cryogun barrel or stem, and the cryoprobe tip. On some units, the on/off switch for the gas valve is located on the cryogun. Activation triggers vary in function. On some units, depression of the trigger initiates the freeze, while on others it defrosts the probe tip. Most triggers feature a locked position setting so that the trigger need not be depressed during the freeze.

Cryoprobe Tips

Cryoprobe tips must be made of a good thermal conducting metal, such as silver, gold, or copper. The interchangeable tips are available in various shapes and sizes to enable maximum contact of the tip with the tissue but avoid freezing of nondiseased areas. Cryoprobe tips should be disinfected following treatments, usually with a chemical disinfectant, although some tips can be autoclaved. Some cryosurgical units feature pyrometers, which indicate the actual temperature of the activated cryoprobe tip. The measurement ensures appropriately generated cryosurgical temperatures within the tip.

Thermocouple

Successful cryotherapy is dependent on adequate depth and extent of freeze and subsequent cryonecrosis. The superficial extent of freeze can be visually measured; however, the depth of freeze cannot. Variations in vascular flow and distribution to tissues influences iceball geometry.[8] *Thermocouples* are temperature-sensing devices that, when used with a pyrometer, permit actual measurement of temperature within tissue or lesions. Clinically, the thermocouple is in a needle that can be inserted into the tissue to a predetermined depth. Accurate documentation of lethal tissue temperatures ensures eradication of diseased tissue and, conversely, protection of normal adjacent tissue.

Methods of Evaluation

All cryosurgical equipment manufacturers or distributors in the United States were solicited to provide units and product specification data for critical review during the summer of 1991. Every manufacturer agreed to participate. Each cryosurgical unit was independently evaluated by the authors, an experienced cryotherapist and a mechanical engineer. Qualitative observations of design and function and quantitative measurements of performance were made on seven nitrous oxide and one liquid nitrogen cryosurgical unit. The investigators were blinded to the manufacturers' suggested prices for each unit until all observations had been documented.

Equipment and Materials

Experimental conditions were standardized and controlled for all phases of evaluation. Room ambient temperature, amount of water-soluble gel (0.1 mL), medical grade nitrous oxide or liquid nitrogen, amount of force applied to the media by the cryoprobe tips, degree of

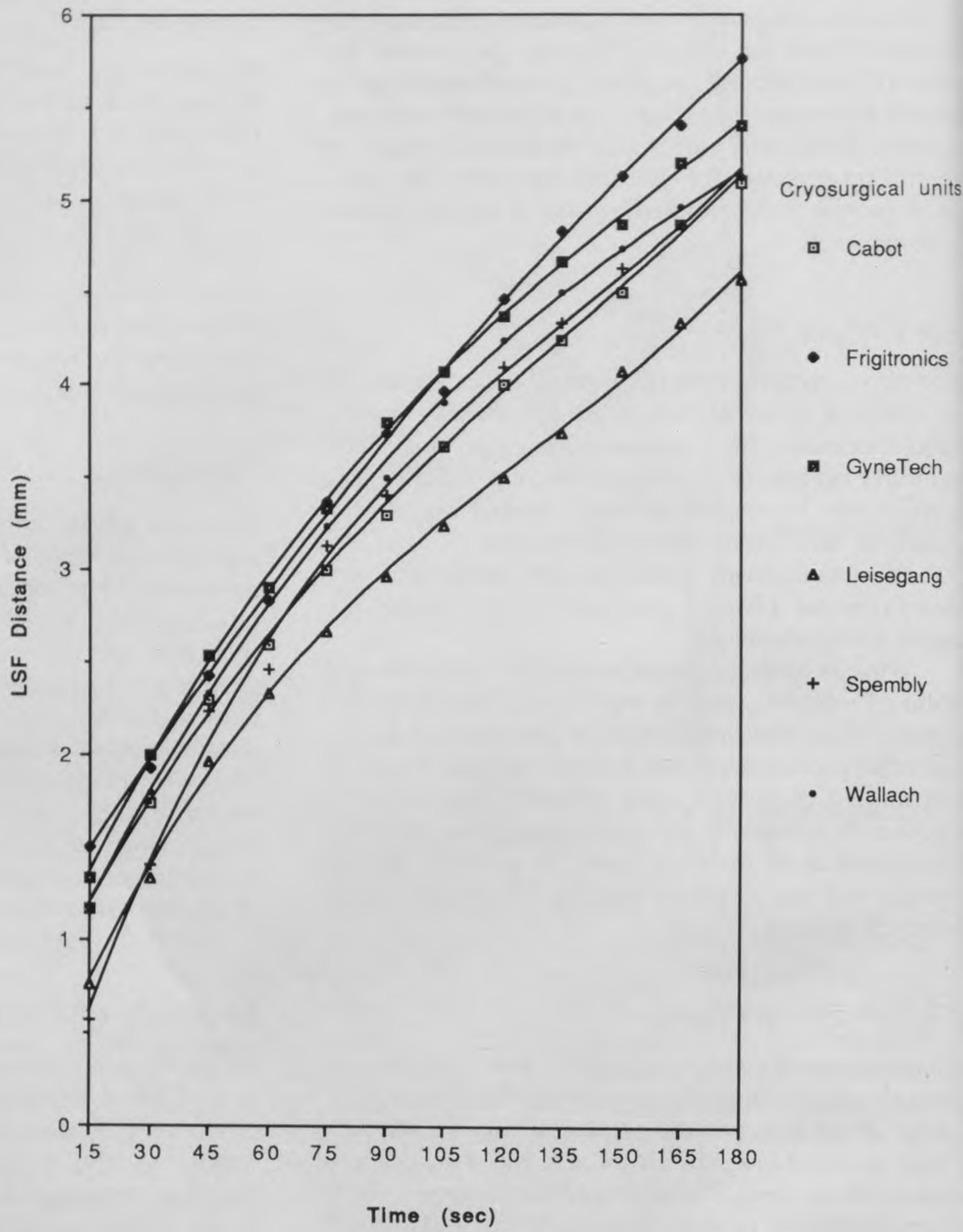

Figure 3. The lateral spread of freeze for the cryosurgical units evaluated using lean pork media and a 19-mm, flat cryoprobe tip. Data represent the mean of three trials.

probe contact, and cryoprobe tip size (19 mm flat) were uniformly standardized. Nonliving biologic materials with comparable water content and osmolality to living tissue are typically used to simulate the thermophysical properties of tissue for equipment testing purposes during cryobiologic research.[8–10] Gelatin media and lean pork were used as target media.

A thermocouple with a LCD digital pyrometer unit was initially equilibrated to confirm true temperature. The same pyrometer was then used consistently throughout the investigation. The pyrometer provided continuous thermal data. Fully filled tanks were used to begin each investigation phase; pressure gauges were required to confirm adequate gas pressure throughout the evaluation. Following each freeze cycle, cylinders were allowed to fully regenerate overnight.

Performance Characteristics

The performance characteristics of each cryosurgical unit were objectively evaluated. The lateral spread of freeze (Figure 3) for each unit represents the mean performance of the equipment during the final three trials based on the degree of uniformity and consistency achieved. Linear measurements of the distance between the 0°C isotherm and the cryoprobe tip margin were recorded every 15

Table 1. Cryosurgical Unit Performance

Function	Cabot MT-700	Frigitronics CryoPlus	GyneTech GT-1S	Leisegang LM-900	Spembly PCG 9R	Wallach WA-1000B*	Brymill Mini-Cryogun
Defrost time (sec)†	3	4	5	3	6	2	320
Recovery zone (mm)‡	2.0	1.9	2.1	1.6	1.8	1.7	—
Time (sec) for −20°C isotherm at 3 mm§	331	310	252	342	361	229	—
Freeze time (sec)‖	480	493	232	459	576	271	—
Refreeze time (sec)¶	159	241	36	71	230	241	—

The performance of the Wallach WA-1000B was equivalent to that of the Wallach LL-100.
†*Time required to defrost cryoprobe tip following a one minute freeze.*
‡*Distance between the −20°C and 0°C isotherms.*
§*Time (in vitro, pork) after freeze activation for a thermocouple to detect the −20°C isotherm placed 3 mm from the cryoprobe tip margin.*
‖*Time (in vitro, gelatin) required for thermocouple placed 3 mm from the cryoprobe tip margin to indicate −20°C during freeze.*
¶*Freeze time required for thermocouple placed 3 mm from the cryoprobe tip margin to indicate −20°C after gelatin thawed to 0°C following initial freeze.*

seconds. The freeze times were determined by measuring the number of seconds required for the thermocouple, which had been placed 3 mm lateral to the cryoprobe tip, to indicate a temperature of −20°C. The gelatin media was allowed to thaw to 0°C, then a second freeze was initiated. The interval of time for the thermocouple (at 3 mm from the tip margin) to reach −20°C was recorded as the *refreeze time*. The data represent the mean of the times obtained during three trials (Table 1). The time for each unit to produce a −20°C isotherm 3 mm from the tip margin was recorded as the *isotherm generation time*. The distance lateral to the 3-mm reference thermocouple at −20°C representing the 0°C isotherm was also noted and was recorded as the recovery zone (Table 1). Cryoprobe tips (19 mm) were frozen for 60 seconds, then either the defrost trigger or defrost mode was fully activated. The time required to completely defrost the tip was recorded as the defrost time (Table 1).

The Cryosurgical Units

Design characteristics and functional or operational features were considered during the evaluation process (Table 2). Individual unit performance data are found exclusively in Table 1 and Figure 3.

Cabot MT-700

The Cabot MT-700 (Cabot Medical Corporation, Langhorne, Penn) cryosurgical unit (green gun) is familiar to many cryotherapists. The materials used to manufacture the unit are of good quality. The unit design is popular because of the position of the on/off switch, which is located on the cryogun stock. The single, 3-position trigger compromises working space during colposcopy, however, when locked in the forward position. Instrumentation room is further compromised by a long stock on the cryogun and the entry of the tubing into the stock. The gas exhaust portal from the pressure regulator exits horizontally, and if scavenging tubing is not in place, accidental freeze of a bystander can result.

Functionally, the freeze is initiated by either locking the trigger forward or depressing the trigger. Defrost is activated by returning the trigger to a neutral position or turning off the unit. The switches are conveniently located to facilitate cryotherapy. Of note, the cryogun shaft became cool during the freeze and the distal shaft frosted along with the trigger housing.

The Cabot MT-700 was rated above average, except for performance, and appeared to be a dependable, sturdy cryosurgical unit.

Frigitronics CryoPlus

The Frigitronics CryoPlus (Frigitronics, Shelton, Conn) equipment incorporates many features not seen in the standard cryosurgical unit. Construction materials are all of good quality, and there are several notable design features. The cryoprobe tip and probe shaft are incorporated into one unit. This unit attaches proximally within the gun body, which ensures that all pressure seals are removed from possible patient contact. The design also permits simultaneous probe and shaft disinfection or sterilization. A blue nylon cover enhances the overall appearance of the unit. The CryoPlus features an analog pyrometer that can determine both the temperature of the cryoprobe tip and that of the thermocouple accessory. A switch located on the pyrometer housing enables instantaneous selection of temperature indications from either the cryoprobe tip or the thermocouple.

An on/off switch is located on the pressure gauge

Table 2. Cryosurgical Unit Features

VARIABLES	CABOT MT-700	FRIGITRONICS Cryoplus	GYNETECH GT-1S	LEISEGANG LM-900	SPEMBLY PCG 9R	WALLACH LL 100	WALLACH WA-1000B	BRYMILL Mini-Cryogun
Gas Type	N_2O	N_2O	N_2O	N_2O	N_2O	N_2O	N_2O	LN_2
Pressure Gauge Indicator	kg/cm²	PSI	kg/cm²	PSI	PSI / kg/cm²	kg/cm²	kg/cm²	N/A
Gas Cylinder (20 lb.) included	YES	YES	YES	YES	YES	YES	$199	N/A
Cryotip holder included	Available	YES	NO	YES	$175	YES	YES	NO
Cryotip material	silver	gold-plated copper	silver, alloy, copper	silver	chrome-coated nickel or silver	chrome-coated nickel or brass	chrome-coated nickel or brass	teflon-coated copper or brass
Cryotip options	20	18	12	14	35	20	20	18
Cryotips included in price	4	None	4	6	4	None	None	5
Price/Cryotip	$170	$325-385	$150	$135	$175	$165	$165	>$60
Autoclavable cryotips	NO	YES	NO	NO	YES	NO	NO	NO
Cryogun holder	YES	YES	YES	YES	NO	YES	YES	NO
Distance – Tip to gun front (cm)	20.3	18.3	18.8	18.4	10.2	18.1	18.1	14.8
Distance – Tip to gun end (cm)	38.6	23.5	32.8	30.5	22.3	24.6	24.6	29.7
Instrumentation room (colpo)	Poor	Superior	Good	Excellent	Unacceptable	Superior	Superior	Poor
Freeze activation (trigger)	Depress	Release	Depress	Depress	Release	Depress	Depress	Depress
Defrost activation (trigger)	Off/Release	Depress	Full Depression	Off/Release	Depress	Separate Trigger (Depress)	Separate Trigger (Depress)	Release
On/Off switch position	Cryogun	Pressure Gauge	Trigger	Pressure Gauge	Pressure Gauge	Trigger	Console	Trigger
Triggers	1 (3 position)	1 (2 position)	1 (3 position)	1 (3 position)	1 (2 position)	2	2	1 (2 position)
Trigger lock	YES	Release is on	YES	YES	Release is on	YES	YES	NO
Tubing entry position	Stock	Handle	Handle	Handle	Stock	Handle	Handle	Stem
Pyrometer type	NO	Analog	NO	NO	NO	NO	Digital	Analog
Thermocouple	—	$175	—	—	—	—	$265	YES
Cryoprobe tip monitor	—	YES	—	—	—	—	YES	YES
Carry case included	NO	Available	YES	YES	YES	YES	N/A	YES
Cart included	YES	YES	YES	YES	YES	YES	YES	N/A
Repair replacement	NO	FEE	FEE	YES	YES	NO	NO	NO
Warranty (Parts/Labor)	1/3 yr.	3 yr.	5 yr.	5 yr.	1 yr.	1 yr.	1 yr.	—
Price	$1,650	$1,695	$1,565	$1,545	$2,430	$1,372	$3,295	$1,095
Ease of use	Below Average	Very Good	Superior	Very Good	Very Good	Superior	Superior	Poor
Overall construction	Very Good	Excellent	Excellent	Excellent	Excellent	Superior	Superior	Average
Recommendation	Good	Excellent	Superior	Very Good	Very Good	Superior	Superior	Fair

RATING SCALE

- Superior
- Excellent
- Very Good
- Good
- Average
- Below Average
- Fair
- Poor
- Unacceptable

pyrometer assembly. The freeze is initiated by merely turning the switch. Defrosting is initiated by depressing the gun trigger. There is some accumulation of distal shaft frost during freeze and frosting of the nitrous oxide tubing at a point 18 inches distal to the tubing entry into the gun base. The square shape of the handle makes the gun awkward to grasp and somewhat hampers maximum surgical control.

The Frigitronics CryoPlus unit allows documentation of both generated and tissue level temperature measurements, which are critical for reliable and adequate cryotherapy. Several design features are notable and considered innovative. The unit's performance was rated above average.

GyneTech GT-1S

The GyneTech GT-1S (GyneTech Instrument Co, Burbank, Calif) is manufactured from high-impact quality materials. The unit features several notable design innovations. A 3-position trigger on the cryogun enables fingertip control of all procedures, as proper operation is not dependent on switches located elsewhere. The O-rings are recessed into the tip to prevent O-ring blowout or failure. The gas tubing enters the handle and therefore does not obstruct the procedure.

Freeze is activated by depressing the 3-position trigger to the second position where it locks into place. Defrost is activated by depressing the trigger to the third position. When released at this position, the trigger automatically returns to the first position. A unique feature of this unit is that probe tips can be changed without closing the gas cylinder or turning a distant switch. This unit therefore allows the greatest control from a single position on the gun.

The GyneTech GT-1S cryosurgical unit includes impressive design characteristics, is functionally superior to others units and demonstrated excellent overall performance.

Leisegang LM-900

The Leisegang Model LM-900 (Leisegang Medical, Inc, Boca Raton, Fla) cryosurgical unit is compact in design. The 4-position cryotip holder is built in as part of the pressure gauge console unit. The on/off switch is also located on the console. The sculptured gun handle grip is one of the most comfortable when compared with the other cryosurgical unit guns evaluated. The nitrous oxide tubing enters the handle, and there is not a long stock on the cryogun. Leisegang also provides cleaning plugs that can be screwed into the probe tips before immersing them in disinfectant.

Freeze is initiated by turning the switch located on the pressure gauge to the ON position and pressing the 3-position trigger either down or forward. Defrost is activated by turning the unit off or quickly depressing the trigger. Some minor frost accumulates on the distal shaft and trigger housing much like that seen in the Cabot unit.

The Leisegang LM-900 cryosurgical unit compared favorably with the other units evaluated, although overall unit performance was somewhat below average.

Spembly PCG 9R

The Spembly cryosurgical unit (Surgical Medical Instrument Corporation, Old Saybrook, Conn) is a streamline, modern-appearing device. An adaptor is required for the unit to fit a standard 20-lb nitrous oxide tank. Spembly offers a large variety of accessory detachable tips. The on/off switch consists of a large dial located on the pressure regulator that can be easily adjusted. Of note, there is no gas "needle" at the end of the cryoprobe shaft, but simply threads to attach the probe tips. The gun barrel is marketed in two lengths to accommodate different cryosurgical procedures.

To activate the freeze, the switch needs to be in the ON position. To defrost, the switch must remain in the ON position and the trigger must be depressed.

The Spembly unit is suitable for office-based procedures, but its performance was below average.

Wallach LL100

The Wallach LL100 cryosurgical unit (Wallach Surgical Devices, Inc, Milford, Conn) is well made and features uniquely designed components. The cryoprobe tip holder is included in the console along with a pressure regulator. The Wallach gun handle is uniquely tailored to allow a comfortable grip and is angled to allow appropriate visualization. The hose exits the handle base.

The Wallach gun has two triggers. When the left trigger is depressed, the freeze is activated and the trigger locks into position. When the trigger on the right is depressed for defrosting, the trigger on the left releases. Therefore, any confusion as to whether the therapist is freezing or defrosting is eliminated by use of two triggers. The O-ring is encapsulated so that there are no O-rings to replace.

The Wallach LL100 is a basic cryosurgical unit that features many unique design characteristics to facilitate cryosurgical procedures. The unit's performance was rated well above average.

Wallach WA-1000B

The Wallach WA-1000B cryosurgical unit is essentially more sophisticated than the LL100. The WA-1000B is a mobile freezer system with an enclosed gas cylinder and a work station or console situated atop the stand. A cryogun canister is located on the console along with the on/off switch. An LCD digital timer with a reset button and an LCD digital pyrometer are positioned atop the work surface. The pyrometer monitors both thermocouple and cryoprobe tip temperatures by adjusting a selection switch on the side of the unit. The pressure gauge is also positioned on the console top. The unit is visually appealing.

The function and performance characteristics of the WA-1000B are of the same high quality as the LL100. The Wallach 1000B is an impressive cryosurgical unit that is equipped to perform special functions with temperature-monitoring devices included.

The Brymill Mini-Cryogun

The Brymill Mini-Cryogun (Brymill Corp, Vernon, Conn) is a liquid nitrogen unit different from the nitrous oxide units included in this investigation. The hand-held device is lightweight and must be manually replenished with liquid nitrogen. The unit comes with a carrying case, which includes a thermocouple monitoring unit with an analog pyrometer.

The functional characteristics of this unit are troublesome when compared with those of the nitrous oxide units. The unit is difficult to grasp. The exhaust tubing flails after initiation of the freeze. The frozen silicone tubing was noted to fracture into small pieces with minimal trauma. Some condensation on the canister top developed during freezing. The room for instrumentation is limited when the unit is used with a colposcope. Freeze is initiated by depressing the trigger, and defrost is initiated by a release of the trigger. The unit must be held upright or at least at no more than a 45° angle to prevent sudden pressure release from the valve.

The Brymill Mini-Cryogun is a comparatively inexpensive cryosurgical device with several demonstrated limitations.

Discussion

The nitrous oxide cryosurgical units evaluated differed in design, function, and performance. Clinically important distinctions among some cryosurgical units were noted in each of these categories. For example, the unique Frigitronics tip design minimizes the risk of inadvertent thermal injury to the patient. The long barrel, trigger lock, stock, and stock tubing entrance of the Cabot make magnified gynecologic procedures difficult and prevent complete tissue visualization. The low profile and tubing entry position of the Wallach cryogun permitted the best visibility, especially when used in a confined region. Physicians who treat malignant or possibly premalignant epithelial diseases with cryosurgery should consider using a thermocouple such as that offered by Frigitronics, Wallach, and Brymill.

The functions of the units varied. The GyneTech unit allowed maximum control of function from one site (the gun handle). The pyrometer systems of the Wallach and Frigitronics units permitted monitoring of the cryoprobe tip temperature, which provided instantaneous feedback of the unit's function. Units varied in activation function, but these differences were not considered clinically relevant, and only significant in terms of individual operator preference.

Tremendous performance variability among units was encountered. The rapid combined freeze and refreeze times of the GyneTech unit (268 seconds) contrasted sharply with the Spembly unit (806 seconds). The efficiency advantage demonstrated equated to a difference of nearly 9 minutes, or three times the duration of the freeze. The Wallach −20°C isotherm time (229 seconds), generated using a different target media, also contrasted with the Spembly unit (361 seconds), which equated to a greater than 50% interval reduction. Such factors may be critically important for a busy office practice. The slow defrost of the Brymill unit is similarly noteworthy and prolongs the process more than 5 minutes. Granted, defrost may be facilitated by the application of warm water to remove the probe, but then an additional procedure must be undertaken.

The documented differences of recovery zone measurements, although minimal, denote marked variability, which may affect therapy outcome. For practical cryotherapy purposes, however, a 2-mm estimate will generally suffice to ensure a lesion-encompassing lethal zone.

A recommendation of a single cryosurgical unit is impossible. However, based on objective performance criteria alone, three nitrous oxide units deserve special recognition. The Wallach, GyneTech, and Frigitronics units demonstrated a scientifically validated level of achievement that was superior to other units. It should be noted that this observation was made irrespective of unit cost. The decision is based on the recognition that a more rapid freeze produces the best therapeutic results.[4] In addition, procedural speed proportionally influences physician productivity and efficiency. Rapid procedure speed also minimizes patient discomfort.

The unique variability of equipment costs, design, and function permits the cryotherapist to select a unit that satisfies his or her technical requirements and provides procedural comfort. It should be emphasized that each unit allows adequate performance of cryosurgery. Satisfactory treatment, however, is highly dependent on the therapist's knowledge of cryosurgical technique and his or her technical skill.

Acknowledgment

Rhonda Craig is gratefully recognized for her review of the manuscript and her creative contribution to the tables.

References

1. Townsend DE, Richart RM. Cryotherapy and carbon dioxide laser management of cervical intraepithelial neoplasia: controlled comparison. Obstet Gynecol 1983; 61:75–8.
2. Richart RM, Townsend DE, Crisp W, et al. An analysis of "long-term" follow-up results in patients with cervical intraepithelial neoplasia treated by cryotherapy. Am J Obstet Gynecol 1980; 137:823–6.
3. Garamy G. Engineering aspects of cryosurgery. In: Rand RW, Rinfret AP, von Leden H, eds. Cryosurgery. Springfield, Ill: Charles C Thomas, 1968:92–132.
4. Townsend DE. Cryosurgery. Surg Clin North Am 1978; 58:97–108.
5. Creasman WT, Weed JC Jr, Curry SL, Johnston WW, Parker RT. Efficacy of cryosurgical treatment of severe cervical intraepithelial neoplasia. Obstet Gynecol 1973; 4:501–6.
6. Torre D. Understanding the relationship between lateral spread of freeze and depth of freeze. J Dermatol Surg Oncol 1979; 5:51–3.
7. Gage AA. What temperature is lethal for cells? J Dermatol Surg Oncol 1979; 5:459–64.
8. Augustnowicz SD, Gage AA. Temperatures and cooling rate variations during cryosurgical probe testing. Int J Refrigeration 1985; 8:198–208.
9. Zacarian SA. Is lateral spread of freeze a valid guide to depth of freeze? J Dermatol Surg Oncol 1978; 4:561–3.
10. Lentz CP. Thermal conductivity of meats, fats, gelatin gels and ice. Food Technology 1961; 15:243–7.