Some readers may be surprised to see described here a technology unit dating from 1992. Since this machine is simply perfect for critical ultrasound, and is still manufactured at the time of the present edition (some regular updates have involved only slight esthetic changes), we will just describe in two steps why we have not felt like changing this basic apparatus. In this chapter, we will simply describe it. In Chap. 30, we will compare it with the recent products in the market. Its main feature is its simplicity, in a field where a simple machine can really optimize the management of the critically ill.

Critical ultrasound heralds a new discipline (that we can temporarily call ultrasound-enhanced critical medicine). The more we can make it simple, the more it will become widespread. In this chapter, we aim at sharing the vision that our unit has given us since 1992. The reader is free to buy any machine— at a time when the possibilities are profuse between the cumbersome sophisticated echocardiography machines and the ultra-portable market. These lines are simply our message.

Some doctors are persuaded that the modern up-to-date machines are better than older ones. This is not true if these machines have not been specifically designed for critical care, and for the most vital organ (the lung).

Some doctors are persuaded that the laptop revolution is the factor which initiated the birth of critical ultrasound. The craze without precedent for these machines comes from a slight confusion: a machine which is quite small (i.e., a laptop) is of great interest for those who work outside the hospital, but not necessarily for the majority who work inside. Smaller machines existed long before.

A Short Version for the Hurried Reader

We use an intelligent machine, which is still manufactured after its 1992 first version.

The feature we appreciate most about this machine is its small size: a width of 29 cm (and only 33 cm with cart), allowing the physician to pass between patient and ventilator, a critical point in a setting where each centimeter counts.

The image quality comes from a cathode ray tube monitor providing analog resolution (please see the figures in this book).

Its keyboard is flat, its design is compact, allowing efficient cleaning, a critical requirement between two patients.

This machine switches on in 7 s, which is basic for time-dependent situations as well as the multiple daily management of critically ill patients.

The cart is smart, since it fits the machine design with a width now of 33 cm. The cart is very important because it is mounted on wheels, which allow transportation of even heavy apparatus (our machine is 12 kg in weight) without effort from the ICU to the ER.

We use this machine because its 5-MHz microconvex probe is suitable for a whole-body analysis and can be qualified as universal. Having a probe that is small and can be applied anywhere without need for change is critical.

We appreciate the low cost of this system, a basic point since it allows easy purchase by the hospital, i.e., easy saving of lives since 1992.

This machine has advanced esthetics, but this particular point is subjective, as opposed to the seven
previous ones, which are scientific. Their smart inter-ac-tions generate a harmonious tool.

As a marketing strategy, in light of the field covered by this 300-page book, our summarized position would be: tomorrow’s medicine using yesterday’s tools.

**A Longer Version: The Seven Requirements We Ask of an Ultrasound Machine Devoted to Critical Use**

We now go into more detail for the unhurried reader. Ultrasound is reputed to be difficult, and it will remain so if we do not take care to consider seven basic requirements that make critical ultrasound simple.

**First Basic Requirement: A (Really) Small Size**

It is critical to find a place between the patient and the ventilator. Each centimeter is important. The important dimension (for those who have high ceilings, i.e., those who work in hospitals) is the width. We invite colleagues to measure the width of their machine (using the instrument of Fig. 30.2 page 298). We keep our 1992 machine since it is small: 29-cm wide on its own, 33 cm with our smart cart: it extends from bed to bed without a problem. For doctors working outside the hospital (airplanes, etc.), please see below.

**Second Basic Requirement: An Intelligent Image Quality**

The reading of most figures featured in this book (which are reprints of reprints...) shows why we respect our 1992 image quality. The analog technology (via a cath-ode ray tube monitor) gives analog image quality. The weight of the monitor is not a problem, thanks to the wheels. Comments about the resolution quality of the digital technologies are available in Chap. 30.

Figure 2.1 shows our definition of a suitable resolution.

**Third Basic Requirement: A Compact Design – for Efficient Cleaning**

We respect our patient, but we also respect the next ones. Accordingly, the cleaning of the machine is a critical point in the ER, and even more in the ICU. Our 1992 machine has a flat keyboard – efficiently washed in a few seconds. We do not advise the choice of machines with too many nooks and crannies for hospital use. The compact and smooth body of our machine is also rapidly cleaned – if necessary (see Chap. 3). What is mandatory for any patient is even more mandatory for the pediatric ICU.

**Fourth Basic Requirement: A Short Start-Up Time**

Time is life in the critically ill (plus multiple daily uses for less critical problems). Critical ultrasound
assumes immediate switch-on. Our 1992 technology has a start-up time of 7 s. Each additional second is an issue.

**Fifth Basic Requirement: An Intelligent Cart**

We find it important to have small machines: a small size allows the unit to be moved easily from bed to bed. For those who work in hospitals (i.e., more than 95% of us), the cart is more than an accessory. It joins together the ultrasound unit, the probe, the contact product, the procedural material, and the disinfectant (and more) in a compact way, and the screen/keyboard is at ergonomic height. The cart cancels the advantage of miniaturization (which is not a problem if the unit is narrow). The cart is equipped with a major, although old, technology: the *wheel*. The wheel was available roughly 4,000 years ago in Mesopotomic cultures. Thanks to the wheel, heavy machines (and mainly our 12-kg machine) are easily transported from bed to bed, from ICU to ER.

Since 1982, the ADR-4000 has had these wheels, and a 42-cm width (Fig. 2.2). These features have allowed the authors to define critical ultrasound at the point of care [1]. Since the ADR-4000’s resolution was suitable for all critical diagnoses (optic nerve apart), we can state that the year 1982 was the point for the ultrasound revolution in the critically ill.

Our intelligent cart fits the unit exactly and does not take up useless place laterally. Figure 2.3 shows how the space is exploited for fixing the main items of equipment and the probe at the top of the monitor.

One role of the cart is to protect the machine. The overall weight and volume (in height) is an invitation to keep the machine within the hospital (i.e., make it difficult to steal).

Those who want to know more about our system should make a rendezvous with the PUMA concept on page 302 of Chap. 30.

**Sixth Basic Requirement: The Access to an Intelligent Microconvex Probe**

The probe is maybe the most important part of critical ultrasound – the bow of the violin.

The traditional ultrasound culture requires cardiac phased-array (2.5 MHz) probes for the heart, abdominal (3.5 MHz) probes for the abdomen, vascular (7.5 MHz) probes for the vessels, and endovaginal probes for the vagina.

We use none of these probes.

All are organ-specialized choices, none having been designed for a critical care use. We have benefited since 1992 from a universal microconvex probe able to answer to all immediate problems (Fig. 2.4). Its head has a unique small footprint: 10 × 20 mm, curved in one axis and linear in the other. It can be applied anywhere, on the numerous hard-to-access areas: intercostal spaces first, for the lung, but also supra-clavicular fossa (lung, superior caval vein), suprasternal area (aorta), the posterior parts of the lung in supine, ventilated patients, the subclavian vein, the popliteal area, the calf, and not to forget the heart. As to larger areas (abdomen), they are analyzed as well without compromise.
The Ultrasound Equipment

Our smart microconvex probe is short: 9 cm. This makes possible investigation of posterior parts in the supine, ventilated patient, such as the posterior wall of the lung (PLAPS point, see page 118), or the popliteal fossa, etc. without effort. Each additional centimeter makes ultrasound more difficult. The usual 12- to 15-cm-long probes discourage the operators from routine lung analysis.

The frequency of our probe is 5 MHz but, more importantly, it provides sufficient image quality, from 1 to 17 cm. This unique range means satisfactory analysis of a subclavian vein as well as the inferior caval vein. Some microconvex probes seen in the recent laptop market have a good intention but have only a 10-cm range, and cannot be considered as universal. Note that a characteristic feature of critical ultrasound is that, apart from abdominal aorta and some veins, the most critical data are extracted from analysis of superficial areas. The lung is the best example. Most of the venous network (internal jugular, subclavian, etc.), peritoneum (pneumoperitoneum), optic nerves are other edifying examples of areas of easy access. As regards the heart, the pericardium is superficial. The ventricules are more superficial than the auricules, which are of lesser importance. In plethoric patients, deep abdominal analysis (pancreas, etc.) is often disappointing, and these patients are eventually referred to CT. Our choice for our single 5-MHz probe has taken this important detail into consideration.

Our probe resolution, slightly similar to an abdominal probe, is far superior to that of cardiac, phased-array probes. Abdominal probes have poor ergonomy. They are useful for measuring the size of a liver – only of interest for the radiologist – but this is not the tool of the intensivist.

The light weight facilitates analysis of the whole body without fatigue (optic nerve, maxillary sinuses, Hunter canal, etc.).

Further discussion about vascular probes is available in Chap. 30. In summary, however, we do not find these probes suitable for use on the human being (they are probably a relic of the industrial, pre-medical era of ultrasound). We use our microconvex probe for all deep veins.

Can one use linear probes for the lungs? This is a fact: lives can certainly be saved using them. The user must just accept to have limited access to the longitudinal approach (that makes lung ultrasound easy), limited criteria for distinguishing B-lines from Z-lines, restricted access to the deep structures, time spent for buying the probe, changing (and therefore disinfecting) probes frequently, and limited access in overly meager patients. Some advocate that lung sliding is easier to detect, but this can be solved simply using M-mode (see page 126).
Using only one probe has several advantages:

1. This allows fast protocols. Once the machine is switched on, the user wastes no time in selecting a probe, or adjusting settings. This is critical for acute respiratory failure, cardiac arrest management, or daily use for any other procedure in the critically ill.

2. It reduces the cost of the equipment and requires buying just one, i.e., saving lives more easily.

3. This is mandatory for performing clean ultrasound. More than one probe, with its cable, is a hindrance for efficient cleaning. When the examiner feels like changing the probe, especially in an emergency, a logical asepsis is quite impossible to achieve (see Chap. 3).

4. This favors simplicity – a golden rule of critical ultrasound.

**Seventh Basic Requirement: An Intelligent, Simple Technology**

This generates simplicity of use associated with low cost. The low cost is a critical point, since each saved dollar saves additional lives.

**Cathode Ray Tube Technology**

See above, our second requirement.

**The Point About Doppler**

We do not use Doppler. This will be a comment throughout this textbook, for each classical application. Additional comments feature in Chap. 30. The main problem with Doppler is the cost (which is triple the cost of a simple machine), having put ultrasound out of the reach of many hospital budgets over the years. This factor has possibly delayed a revolution that could have occurred in 1982 (ADR-4000).

Our daily use is centered around life-saving or very current applications. Observations have showed that Doppler is sometimes required, but on rare occasions for extreme emergency use. We therefore developed the concept of the Doppler Intermittently Asked From Outside: Rare Applications – the DIAFORA concept – for indicating that we are not closed to it. We just ask, from time to time, an outside operator with a complex machine, to come to the bedside. Even more than half the time this is not contributive to the patient (study in process).

We have also envisaged a simple, low-cost alternative: a low-cost continuous Doppler probe, which we arrange to couple with our real-time probe, for having the vessel located, then the Doppler signal. We have not found time to build a serious device for coupling the two probes (indicating that we have not felt an urgent need for using this potential).

**Filters**

We work on natural images. Filters are good for radiologists, by providing an image nice to look at, but we think that they are a hindrance for critical ultrasound. The profusion of recent modes is maybe a marketing policy, or possibly a necessary adaptation to the poor resolution of the flat-screen technology. We regularly inactivate persistence filters, dynamic noise filters, and average filters, which prevent real-time dynamic analysis of vital organs: lung first, heart, vessels, GI tract. Filters creating a lag are not compatible with dynamic analysis. Some modes try to suppress the artifacts. Multibeam mode is maybe the most destructive filter. We are concerned with the desire of manufacturers to suppress these artifacts. This would simply mean “burying alive” lung ultrasound. We will resist this new fashion by any means. We do not clearly see the interest of harmonics and bypass this function. As a rule, we bypass all filters. Critical ultrasound is performed using natural images.

We also consider here the facilities for challenging patients. Some modern modes that advocate making them well echoic should be carefully assessed. For visual comfort, with increasing experience, smoothing the image can be helpful when studying motionless organs (liver).

**Contrast-Enhanced Ultrasound**

This mode is possibly interesting, although requiring special software, and is not accessible with our simple
The Ultrasound Equipment

unit. We will examine this mode in the future, when the full potential of a simple critical ultrasound design will be covered.

Computer Technology

This condemns the user to a long switch-on time (far from our 7-s time) and the permanent risk of bugging, for no benefit.

M-Mode

This is an important function, allowing ideal use of lung ultrasound. Our unit aligns the real-time and the M-mode images on a perfect horizontal plane. See Fig. 2.5, and our comments about those which do not, and the consequences on the diagnosis in Chap. 18 page 165.

To Conclude on this Technologic Point

The most sophisticated modes will be useful to some very specialized centers (cardiac surgery ICU, for instance), but bear in mind that they will be unable to cross bones, air or dressings. These are true limitations of ultrasound. Attending countless workshops using modern laptop equipment, we have become accustomed to them little by little, but are left with feeling a difficulty in using them. They are configured in traditional ultrasound, which critical ultrasound is not, since simple technology is used.

One Critical Word to Summarize

Our Seven Requirements

The smart reader has seen that each part of this machine interacts with the others. The cart fits the machine. The quality is evident from the cathode ray tube monitor, which is light thanks to the wheels, which allows the machine to be secure (not stolen) and easily transported. The monitor allows the top to be utilized, i.e., benefiting from a narrow width, one probe finds a natural place upon this top. This perfect probe allows fast ultrasound with easy cleaning, etc. One word for characterizing this type of completion should be: harmony.

Additional Details

Coupling System

The gel is advocated to be mandatory, since it creates a coupling between probe and skin. Since the dawn of ultrasound, gel gives a traditional vision of a messy, slippery field: a sticky discipline. It makes a nice culture medium. Squeezed by the stressed hand, it generates gurgling noises reminiscent of undesirable digestive noise, never appropriate in dramatic settings. Visions of dried gel that was not wiped, with on occasional hair stuck on the probe, are common. We are persuaded that this image is not excellent for the propagation of ultrasound, and admit that our attraction for ultrasound was during years shadowed by this gel.

We have made gel unnecessary. We elaborated a new contact medium, based on an equimolecular combination. Totally harmless, odorless, applied with a special compress, which is applied onto the area to be scanned, it provides the same image quality. It vanishes after a few minutes. No residual dust is perceptible on
Which Solutions for Teams Already Equipped with Small-Sized Technologies?

The skin. All figures in this book have been acquired using it. This product has nothing but advantages.

The main advantage is a major time saving during critical examinations: the time necessary for passing from an area (lungs) to a remote area (lower veins) is reduced to less than 3 s.

Another major advantage is in extreme emergencies (cardiac arrest): the amounts of gel necessary to make the thorax slippery are a hindrance to resuscitation.\(^1\)

The last, but not the least, main advantage is the comfort of making a clean examination, far from this traditional “sticky mess” (see Fig. 30.1).

Our product has appropriate adiabatic properties and can be used warm, which is appreciated by the conscious patient. Since we have begun using it, ultrasound has become a complete pleasure. Our product, recently patented, will soon be distributed. Ecolight, called the “gel-less gel” by Teresa Liu, is one example among others which show that our vision of ultrasound is simple and user-friendly.

Recording the Data

The hardcopy is useful in order to preserve documents. In extreme emergency situations; a videocassette recorder has three advantages: a shorter examination (taking photographs is not necessary), data that can be read subsequently, and data easier to read than static images.

We now live in the digital era, but VHS technology allows us (even today) to make thousands of recordings and hundreds of presentations. We conclude that the problem of digital or analog is not relevant.

The Problem of Incident Light

Critical ultrasound has to be practiced around the clock. Daylight can bleach the screen. Manufacturers do not always think of systems to prevent this inconvenience. We must imagine several temporary set-ups adapted to each unit. The most promising seems to be sliding panels. A matt black cylinder applied to the screen at an oblique angle (towards the operator’s eye) is another possible solution.

How to Practically Afford a Machine in One’s ICU

We currently see three approaches.

1. To buy a new one. Very few brand names are present in the recent critical care congresses but the buyer who considers the width instead of the height will discover a large choice.

2. To acquire a second-hand machine. Occasionally, the radiology department gets rid of obsolete units and leaves them to whoever wants them. These “old” machines can save lives; some of them can be excellent. Note that cathode ray tubes give better resolution than digital screens.

3. To steal it. The possibility of stealing a machine is an option which must be considered, now that ultrasmall machines have invaded our hospitals. These lines have been written with serious intent, and we want to make colleagues aware of this unpleasant scenario; it has already occurred in prestigious institutions. Fixing a portable unit solidly on a cart is the solution, which immediately makes the ultraminiature technology of lesser relevance. Consequently, the user will benefit from all the disadvantages of low-height machines, and should carefully search the advantages (see Chap. 30). We ask the reader to consider this basic point.

Which Solutions for Teams Already Equipped with Small-Sized Technologies?

That equipment can be used. Indeed, any kind of machine can give useful information. Things are just more difficult, ranging from slightly to extremely. Since the author is accustomed to working with “perfection” since 1992, which he has looked for over several years in the modern laptop market, the index of 100 was given to this system and permanently compared with modern technologies.

Each centimeter in width >33 cm creates additional difficulty (take the cart size into account). Each decrease in resolution <100 detracts from accurate use.

Each button to be cleaned is a hindrance.

\(^1\)We thank Sébastien Perrot who, during a Paris-Taiwan flight, although not physician, opened our eyes to this basic point.
Each second over 7 s for start-up increases psychological barriers.

Each millimeter of surface of the probe head >10 × 20 mm makes access to difficult parts more difficult.

Each centimeter of length of the probe >9 cm makes posterior analysis more difficult.

A wide choice of probes is not necessary, especially if the ideally designed one is missing.

Each additional dollar >16,000 makes purchase more difficult.

Laptop machines which have simultaneously a width >33 cm, a resolution image <100, a number of buttons >1, a start-up time >7 s, a probe length >8 cm, not the suitable probe shape and property, and a cost >$16,000 are not used by the author.

Those who currently lack the necessary equipment but want to have an idea of lung and venous ultrasound made in the spirit of the BLUE protocol (see Chap. 20) will find the best compromise in image quality using the abdominal probes, which have poor ergonomy. They will find the best compromise in ergonomy with the cardiac probes, which have poor image quality. They will find the best superficial resolution using linear probes, which have poor ergonomy and limited field. Not taking into account the properties of our 1992 unit, the modern laptop machines have not decreased the difficulty of ultrasound – which is in its current, traditional state a discipline for experts.

Although we think the community lost an opportunity to discover critical ultrasound in the way of simplicity, we are optimistic and hope for a simple solution (dealt with in Chap. 30).

### Seven important points

1. The important dimension (for optimal mobilization) is the lateral width, not the height.
2. The cathode ray tube technology (not heavy thanks to the wheels of the cart) provides the best image quality.
3. A flat keyboard is easy and rapid to disinfect.
4. An immediate start-up time (7 s) is important.
5. An intelligent cart does not annihilate the advantages of miniaturization.
6. One probe can be used for the whole body (a 1–17-cm range microconvex probe).
7. Doppler and other sophisticated modes (harmonics, etc.) are not of major utility in our setting.

### References