Remote access technology offers tremendous possibilities to the cytometry community.

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The opportunity for low cost, high quality training and supervision is an attractive one to most scientists in the cytometry field. Many have had little if any training, no expertise based locally, or may not have the funds to attend regional or international training courses. In addition, rather than general cytometry they may require assistance with a particular application, which could be accomplished in a number of hours through support from an expert.

Separately, shared resource scientists, also known as core facility staff, are generally responsible for the performance and upkeep of multiple complex instruments, as well as monitoring, training etc. Some acquisitions or cell sorts may take hours for a single run, and with limited staff the scientist is usually multitasking on an hourly basis. Also, if users of the core facility are having problems and staff is unavailable, valuable samples or time may be lost.

There is potential for error at many steps of flow cytometry, including sample preparation, experimental design and fluorochrome selection, instrument set up, compensation, gating, analysis, and interpretation. External/off-site tracking may improve monitoring, and perhaps limit such errors. Also inter- and intra-instrumentation variations can lead to different results for the same sample. A means of unifying performance, setup, and interpretation is vital, in particular with multicenter collaborations. Peer-review of results and analysis, as well as hierarchical approval systems, provides some solutions, but further stream-lining is clearly beneficial.

Remote access technology for cytometry (or remote cytometry) may offer solutions to many such issues and can be performed at very low costs to the institution. There is potential for such systems to facilitate instrumentation monitoring, control equipment in containment areas, speed up vendor service, improve training courses, increase collaborations, and further promote cytometry globally.

Equipment

Multiple software tools are available for remote access (Table 1), and additional requirements are few. Many of the programs are accessible at no charge to non-commercial entities, and virtually all have free trial periods. Some require downloading programs to the local computer, whilst others are solely web-based. Several have video conference and chat options integrated into the software, including the ability to record the session. In addition, the increasing functionality of smart phones is making remote control even more accessible, yet optimal connectivity is still through wired connections.

Table 1. Popular remote access software options (in alphabetical order)

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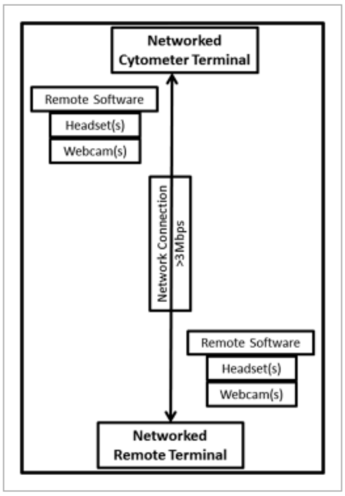
Software	Website	Charge
Ammyy	www.ammyy.com	One-off charges.
Bomgar	www.bomgar.com	One-off charge, then yearly maintenance fee.
Copilot	www.copilot.com	Pay as you go or monthly plans.
Emco	www.emcosoftware.com	One-off charges.
GoToMyPC	www.gotomypc.com	Monthly or Yearly plans.
LogMeIn	www.logmein.com	Monthly or Yearly plans.
TeamViewer	www.teamviewer.com	One-off charges (no charge for non-commercial).
TightVNC	www.tightvnc.com	No charge.
WebEx	www.webex.com	Monthly or Yearly plans (no charge for basic).

The computer terminals must be networked, with a reasonable bandwidth (ideally >3 Mbps), and high-speed network card. A wired network is preferred to a wireless connection (Fig. 1). Once the access software is set up, operation of all proprietary software (including cytometry software be it for sorter or analyzer; acquisition or analysis) should be seamless. In some instances webcams, or remote access software, may interfere with cytometer acquisition software and should be explored prior to use.

Figure 1.

Remote cytometry schematic.



There are varying levels of security for the software itself, some with passwords changing at each session; others with constant access, or permanent passwords, available. Institutional firewalls may compromise connectivity and should be evaluated, and advice and permission should be sought from the information technology department. Indeed some institutional firewalls will not allow any external access but connections from within the organization may still be allowed, and advantageous.

If communicating with an operator, or training at the remote site, a headset (earphones and microphone) should be acquired. If using more than one headset per terminal, compatibility should be confirmed; some USB headsets can only run singly in a system. At least one webcam is an advantage as this allows visualizing the instrument. Many cytometers, in particular sorters, have integrated cameras to allow viewing important internal components, or functions. In the authors' opinion webcams at both ends of the network improves the learning experience, and this visual interaction reinforces the quality of the training session. In addition, ideally only one remote access package should be installed per group/institution to have clear SOPs, software training etc.

Monitoring and Support

As remote access allows the operator to monitor and control the cytometer from any other networked computer, be it across the room or across the globe, cytometers can conceivably be run un-manned for extended periods. This may be particularly useful for cell sorting, where purifying a sample may take anything from a few minutes to many hours. Hence the operator can control the sorter from their office, or any other workstation, should they wish to. In cytometers with autoloaders or carousels, where the process may last an extended duration, the acquisition can be tracked remotely, particularly useful where system clogs are a risk.

Non-experts setting up or running an experiment may frequently run into problems that can be easily remedied, but the shared resource scientist or experienced user may not be on-hand. Allowing such specialists access to view the acquisition setup and data means the problem may be resolved quickly in real time so the user can continue their acquisition without losing important samples or time.

Remote monitoring should enable scientists to easily track performance of instruments, as well as variation between instruments. Via a central workstation all the QC data from the instrument can be analyzed, as well as the information that may be embedded within the list mode files, without the need of additional copies of the. fcs files.

Most cytometers require start-up time to allow the lasers to equilibrate, and the fluidics to stabilize. This can vary between minutes up to an hour, so the possibility of beginning this setup before arriving at the lab is an attractive one. The terminal may be left in a standby state and started up remotely. Alternatively, some packages allow access to a shutdown computer whilst others have automatic boot up functions (e.g., Bomgar, Emco).

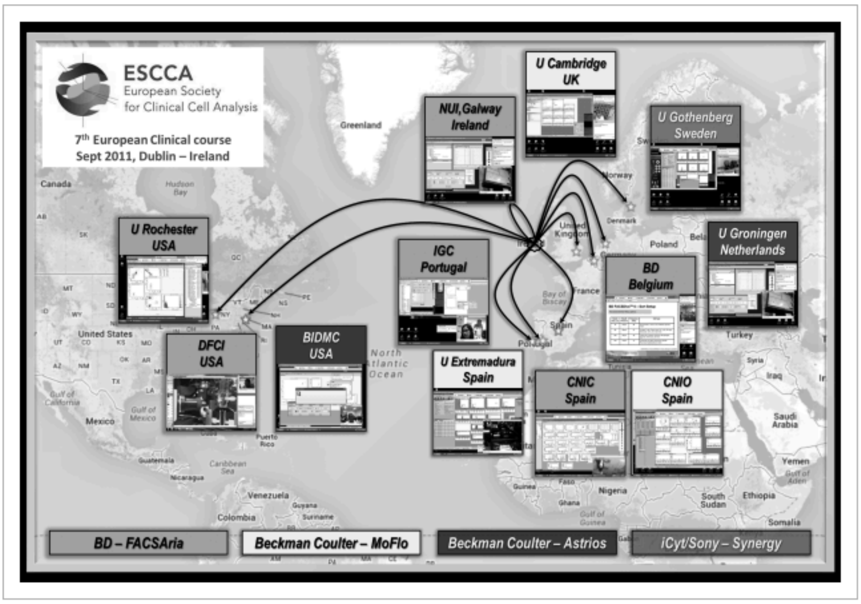
Remote operation can be extended to allow instrumentation specialists access to the cytometer to diagnose, and ultimately fix, software or hardware issues. This will lead to shorter instrument downtime. Indeed vendors are already integrating systems so they can control and adjust the instrument remotely, in particular with motor-controlled focusing lenses on the laser paths. Also, they have automated diagnostic programs to track and identify issues. It is expected that instrumentation manufacturers will further embrace such technology, perhaps to include remote operation of instruments within barriers (e.g., Cat III biohazard conditions), or control of multiple instruments from one workstation. Ultimately all this should lead to decreased service charges as the vendor maintenance costs should be drastically reduced. The opportunity is also there for instrumentation companies to allow potential customers to remotely trial an instrument and software if direct access is not possible.

Training

In 2011, the authors designed a course teaching the fundamentals of cell sorting at the seventh European Course on Clinical Cytometry, associated with the European Society for Clinical Cell Analysis (ESCCA). It supported 32 participants in a class room style set up. Cell sorters are traditionally large, cumbersome instruments with very sensitive electronics and fluidics, with an exceptionally high price tag, so there are obvious difficulties in giving practical training on the sorters to such a large number of participants. We devised a format to link 12 terminals (each with 2–3 trainees) at the course site to 12 remote sites, at core labs throughout Europe and the US (Fig. 2). Various brands of sorters were selected. With headsets and webcams at each remote site, instructors were able to demonstrate the hardware and software components of the sorter, as well as train in sort set up and troubleshooting successfully.

Figure 2.

Lab network for Cell Sorting Training Course, ESCCA, 2011.



This remote aspect complemented the on-site training and lectures, and allowed the students direct access and control of these high-end cell sorters in order to get a more “hands-on” experience at a fraction of the cost of traditional training. It enabled participants to have personal interaction with cytometry experts throughout the world, through one central location. The program in all was generally accepted as being a novel and extremely successful one [1]. To the best of our knowledge, this was the first such course in the world, and it showed the training possibilities that remote access allow.

Such courses can bring scientists, institutions, and companies together to teach and promote cytometry as a powerful tool. They are much more accessible, and affordable, than traditional training courses. They can be developed based on any application or instrument, and indeed other technologies, for example, microscopy and imaging.

Discussion

Although millions of users are availing of remote access technologies daily, it appears anecdotally that there has not been widespread uptake of this technology by the cytometry community. Certainly its full potential has yet to be realized. Though it is certain that many groups are using remote cytometry for their applications, there has been very little published in the last ten years beyond some informal articles [2]. Lorenzana et al. [3], in 2000, used Timbuktu Pro software (Netopia, Motorola) to connect and control a remote computer and cytometer through a direct-dial connection, and discussed the potential this provides. Indeed, Battye [4], in 2001, discussed how the size of cytometry data discouraged their transmission, and hence analyses, over telephone modem connections. However, despite the emergence of broadband technology since, there has been little discussion of using this technology to aid the cytometrist.

The technology and infrastructure have now arrived, and are available in most laboratories in the world, to avail of all the opportunities that remote cytometry offers. Further, new file sharing and cloud technologies such as Google Drive and Dropbox have made connections between groups more straightforward. Above all, these options offer much more economical solutions than the alternatives.

Clinical cytometry is extremely stringent in its precise setup, controls, and gating procedures. Interpretation of results is critical for patient diagnosis and treatment. Such distant access allows collaborators, lab directors, etc. to confirm correct gating and analyses, and hence have greater confidence in the reporting. Specialists can train other sites in the appropriate settings and gating to ensure consistency. The importance in uniformity extends to clinical trials hence this is an important tool in multicentre trials. Combining equivalent SOPs with such access should decrease errors which may occur in inter-institutional collaborations, and ultimately this should all lead to increased standardisation of cytometry protocols in both clinical and research settings.

As discussed, training is aided hugely, and inexpensively, by remote access technology. We believe that there is enormous opportunity to organise structured training to institutes in developing countries. This can be for clinical or research labs, and should be run at minimal costs. A network could be developed whereby groups with the same instrumentation are linked and a training schedule developed. The training plan could be devised by a central committee, and perhaps sponsored by instrumentation companies. We believe the International Society for Advancement of Cytometry (ISAC) may be best placed to lead this initiative, perhaps partnered with the International Clinical Cytometry Society (ICCS) and/or the European Society for Clinical Cell Analysis

(ESCCA). Such programs could be run as on-going collaborations or one-off sessions.

An international network could also be developed to encourage exchange of expertise. Indeed a database could be created based on application, instrument, software, location, etc. Sessions could be charged at agreed or institutional rates. Experts should be recognised, and if appropriate acknowledged in publications. Such a network should raise the profile and promotion of cytometry and its societies, and drive further funding; and will ultimately lead to collaborations and marked advancements in cytometry.

There are obvious practical limitations to such training and systems, such as lack of hardware or connectivity infrastructure in some centres, as well as compatible time zones and shared languages. Many institutions are not permitted to allow external remote access, in particular with regard to data privacy. Also, an intrinsic weakness with such training is that it does not lend itself to supervising sample preparation, general lab techniques etc.

This article is presented to state the opportunities that remote cytometry currently offers the community, and to stimulate discussion on its further potential. We believe that this technology has opened up many possibilities, particularly with regard to philanthropic support and training. We hope the international community will continue to develop systems where we can use these tools to propagate cytometric excellence and improved research, diagnostics, and treatments.

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