In-vivo mass spectrometry - from bacteria to the operating room

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Mass spectrometry is a uniquely sensitive and selective tool for the characterisation of biological systems. The technique is used equally for the analysis of metabolites, lipids, carbohydrates and proteins in biological fluids as well as tissues. Interpretation of mass spectral data is straightforward as the m/z values detected by the instrument directly correspond to the molecular weight and hence the molecular formulae of the species of interest. In contrast to all of these positive features, applicability of mass spectrometric techniques suffer from the intrinsic invasiveness of the technique and its largely unpredictable behaviour in case of complex mixture analysis. Due to these features, mass spectrometric analysis always requires sampling, sample preparation and chromatographic separation of components prior to MS analysis.

In-vivo spectroscopic analysis is generally utilized for the monitoring of biological systems and real-time medical diagnostics where the results are used for immediate decision making. Although mass spectrometry could be an ideal candidate for these applications, the problems described above have successfully halted the deployment of the technology in this area until recently.

The advent of ambient or direct mass spectrometry in the mid 2000's fundamentally changed the landscape and dozens of MS-based technologies amenable for in-vivo analysis have been described. Desorption Electrospray Ionization (DESI) has been successfully used for the direct analysis of skin and mucosal epithelia by multiple groups and other methods such as low temperature plasma (LTP) desorption has also been demonstrated to yield useful spectroscopic information in similar settings. The second major breakthrough in the field was the extension of applications to the domain of surgery and intrasurgical tissue identification. Rapid Evaporative Ionization Mass Spectrometry (REIMS) was originally put forward as the direct combination of electrosurgical tissue ablation and mass spectrometric analysis of the electrosurgically produced aerosol. The REIMS data – primarily featuring signals associated with the complex lipid content of samples – was found to show high histological specificity, allowing the real-time detection of cancerous tissue in course of tumour resection interventions. This application has a huge potential regarding tumour margin clearance, providing a real-time, in-situ tool for eliminating any residual tumour infiltrations. In addition to electrosurgery, a number of other surgical dissection techniques have been successfully combined with mass spectrometric analysis, including laser surgery and ultrasonic ablation (harmonic scalpel and CUSA). More recently, minimally invasive versions of the electrosurgical and surgical laser REIMS have been developed for improved data collection for training and endoscopic interventions. In a parallel fashion, REIMS technology has successfully been employed for the high throughput analysis of bacterial and cell cultures, providing an ultrafast characterisation tool as well as way to understand data collected in-vivo.