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SPEC 2024: International Conference on Clinical Spectroscopy

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This themed collection in *Analyst* on optical diagnostics, draws from the 13th International Conference on Clinical Spectroscopy (SPEC 2024), held from 2–6 June 2024 in Ioannina, Greece. This biennial conference is the flagship event of CLIRSPEC, the International Society for Clinical Spectroscopy (https://clirspec.org/) and was chaired by Dr Martha Vardaki and Prof. Nikolaos Kourkoumelis. The SPEC 2024 conference confirmed its core mission to connect the dots between spectroscopy and clinical application. Since its inception, the conference has grown into a vibrant gathering for academic, clinical, and industrial communities to share advances in spectroscopy with the potential to transform healthcare. The scientific agenda of SPEC 2024 was structured around six key themes: Clinical Translational – Therapy Intersection; Theranostics – Therapy Monitoring; *In vivo* and *Ex vivo* Clinical Translational Studies; Clinical Applications; AI, Data Science and Computational Methods; and Emerging Technologies – Multimodal Systems.

Several contributions highlighted the growing potential of spectroscopy to guide therapeutic strategies and improve clinical workflows. Albahri *et al.* (https://doi.org/10.1039/D5AN00507H) presented a multi-platform approach combining Fourier-transform infrared (FTIR) spectroscopy, optical photothermal infrared (O-PTIR) spectroscopy, and MALDI-TOF mass spectrometry, to classify periodontal pathogens. Their findings underscored the diagnostic promise of bacterial lipid and protein signatures in supporting targeted interventions for periodontitis. The convergence of diagnostics and therapeutic monitoring was further underscored by the work of Udensi *et al.* (https://doi.org/10.1039/D4AN01337A), who employed Raman spectroscopy to assess the systemic effects of dietary supplementation with macular pigment carotenoids in open angle glaucoma patients. By analyzing blood serum samples before and after supplementation with macular pigment carotenoids, the study demonstrated spectroscopic signatures consistent with enhanced antioxidant status and carotenoid presence. The transition of spectroscopy from bench to bedside was clearly demonstrated in both *in vivo* and *ex vivo* clinical studies. Bouzerda *et al.* (https://doi.org/10.1039/D5AN00230C) investigated the potential of FTIR and Raman microspectroscopy to distinguish between types of pancreatic cystic lesions using *ex vivo* analysis of cyst fluid. Pancreatic cysts pose a significant clinical challenge, as current diagnostic tools often lack the specificity to reliably discriminate between benign and malignant forms, leading to unnecessary surgeries or missed diagnoses. The authors demonstrated that Raman spectral profiles of protein, lipid, and nucleic acid content, could effectively differentiate between mucinous and non-mucinous cysts. Migdalski *et al.* (https://doi.org/10.1039/D5AN00272A) applied two-dimensional correlation spectroscopy to Raman data from malaria-infected red blood cells, revealing subtle but informative spectral correlations tied to parasitemia levels enhancing sensitivity in infection tracking. Similarly, Combescot *et al.* (https://doi.org/10.1039/D4AN01489H) presented a proof-of-concept study on the use of mid-infrared spectral imaging to differentiate ganglionic (normal) from aganglionic (abnormal) colon tissue in Hirschsprung disease. By analyzing tissue sections from formalin-fixed samples, their approach revealed biochemical distinctions complementary to the standard histology.

Other contributions addressed critical diagnostic needs across multiple oncological contexts. Pantazi *et al.* (https://doi.org/10.1039/D5AN00024F) investigated extracellular vesicles (EVs) derived from ovarian cancer cell lines using FTIR spectroscopy and biochemical assays. Their findings revealed distinct spectral differences between EVs from malignant and non-malignant sources, particularly in lipid and carbohydrate spectra regions. The findings suggest that EVs carry cancer-specific biochemical signatures that could be exploited in liquid biopsies for ovarian cancer. Frimpong *et al.* (https://doi.org/10.1039/D4AN01293C) applied Raman spectroscopy to fresh-frozen ovarian and peritoneal tissues to correctly classify ovarian cancer from benign and borderline tissues. Their spectral classification model achieved high sensitivity and

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specificity in differentiating malignant, borderline, and benign ovarian tissues, even in patients who had received neoadjuvant chemotherapy. The technique also proved effective in identifying cancerous infiltration in peritoneal tissue, a critical yet challenging clinical task. Another oncological study by Gladwell *et al.* (https://doi.org/10.1039/D5AN00126A) applied FTIR imaging with isotopically labeled arachidonic acid (AA) to probe lipid metabolism in prostate cancer cells. Invasive prostate cancer cell lines took up the deuterated AA and metabolized it *via* the COX-2 pathway, producing inflammatory eicosanoids. The FTIR maps revealed phenotype-specific lipid metabolism with aggressive cells rapidly incorporating ω-6 AA into pro-tumorigenic metabolites.

A particularly dynamic area of the conference was the integration of data science and machine learning into clinical spectroscopy. Sharaha *et al.* (https://doi.org/10.1039/D5AN00360A) addressed a critical gap in early cancer diagnostics by combining Raman spectroscopy with a machine learning workflow to distinguish between normal, precancerous, and malignant phenotypes in a well-characterized mouse fibroblast model. Using ANOVA-based feature selection and log-likelihood decision logic, they identified spectral markers of malignant progression and achieved high classification accuracies. Wang *et al.* (https://doi.org/10.1039/D5AN00117J) explored the utility of FTIR imaging combined with a deep learning classifier to predict malignant transformation in oral epithelial dysplasia (OED), a precancerous condition that may progress to oral squamous cell carcinoma (OSCC). By analyzing spectral data from multiple epithelial regions per sample, they found that OED with spectral features resembling OSCC carried a higher risk of transformation. Pavlou and Kourkoumelis (https://doi.org/10.1039/D5AN00452G) introduced PyFASMA, an open-source Python toolkit for Raman spectra analysis. PyFASMA provides modular pipelines for all common preprocessing steps (cosmic spike removal, smoothing, baseline correction, normalization) and multivariate analysis (PCA, PLS-DA), plus bands deconvolution. It is designed for use in Jupyter notebooks, for reproducibility and automation. The authors demonstrated PyFASMA on a case study of bone spectra, showing that it can robustly extract biochemical differences between healthy and osteoporotic samples.

In the context of emerging technologies, Ferguson *et al.* (https://doi.org/10.1039/D5AN00046G) showcased the diagnostic power of rapid, high-resolution IR imaging using quantum cascade laser (QCL) microscopy. The new QCL-based microscope can acquire full mid-IR (fingerprint region) hyperspectral images of prostate cancer tissue microscope slides in under 30 minutes. The ability to extract diagnostic cues across wide spectral windows in clinically relevant timeframes is a meaningful step toward embedding infrared microscopy into hospital diagnostic pipelines. Beyond application-driven studies, fundamental advances were also prominently featured. Vincent *et al.* (https://doi.org/10.1039/D5AN00136F) provided a detailed FTIR spectroscopic characterization of chondroitin sulfate-E oligosaccharides and showed molecular signatures unique to different sulfation patterns (C-4 *vs.* C-6), biotin tags, and chain lengths. This work describes a molecular fingerprinting toolkit for glycomics and drug delivery research, with significant potential in cancer biology.

In addition to the original research papers, this collection features a timely and insightful Perspective article by Baranska *et al.* (https://doi.org/10.1039/D5AN00419E), reflecting on the first decade of the CLIRSPEC. The authors describe how CLIRSPEC grew into a global community of researchers working toward a common goal: turning spectroscopic innovation into meaningful improvements in healthcare. The society's vision includes fostering early-career development, expanding inclusivity, organizing collaborative projects, and ensuring that spectroscopic advances are grounded in real-world clinical needs. SPEC 2024 embodied these principles, from lively poster sessions to the Clinical Perspective Round Table that concluded the meeting, providing the framework for community building and cross-disciplinary dialogue.

We thank all the contributors, and we look forward to SPEC2026, to be held at Vanderbilt University in Nashville, Tennessee, from 16–20 May 2026 (https://www.spec2026.org/). This upcoming meeting carries the subtitle "*Light for Life: Lab to Clinic*" and with rightful synchronicity, it opens on 16 May, the very date of the UNESCO-designated *International Day of Light*. This timely convergence of science and symbolism offers more than a planned coincidence; it is a celebration of light as both subject and medium of our work. As Pink Floyd once urged, "Let There Be More Light", a fitting anthem for a field that continues to shine light on disease mechanisms, diagnostics, and clinical decision-making.