Intraoperative Angiography Provides Objective Assessment of Skin Perfusion in Complex Knee Reconstruction

Cody C. Wyles BS, Michael J. Taunton MD, Steven R. Jacobson MD,
Nho V. Tran MD, Rafael J. Sierra MD, Robert T. Trousdale MD

Published online: 9 July 2014
© The Association of Bone and Joint Surgeons® 2014

Abstract

Background Wound necrosis is a potentially devastating complication of complex knee reconstruction. Laser-assisted indocyanine green angiography (LA-ICGA) is a technology that has been described in the plastic surgery literature to provide an objective assessment of skin perfusion in the operating room. This novel technology uses a plasma protein bound dye (ICG) and a camera unit that is calibrated to view the frequency emitted by the dye. The intention of this technology is to offer real-time visualization of blood flow to skin and soft tissue in a way that might help surgeons make decisions about closure or coverage of a surgical site based on blood flow, potentially

avoiding soft tissue reconstruction while preventing skin necrosis or wound breakdown after primary closures, but its efficacy is untested in the setting of complex TKA.

Questions/purposes The purpose of this study was to evaluate perfusion borders and tension ischemia in a series of complex knee reconstructions to guide optimal wound management.

Methods Beginning in mid-2011, an LA-ICGA system was used to evaluate soft tissue viability in knee reconstruction procedures that were considered high risk for wound complications. Seven patients undergoing complex primary or revision TKA from 2011 to 2013 were included. These patients were chosen as a convenience sample of knee reconstruction procedures for which we obtained consultation with the plastic

The institution of one or more of the authors (MJT, SRJ, RJS, RTT) has received, during the study period, funding from DePuy Orthopaedics, Inc (Warsaw, IN, USA), Wright Medical Technology, Inc (Arlington, TN, USA), MAKO Surgical Corp (Ft Lauderdale, FL, USA), DJO Global (Vista, CA, USA), LifeCell Corporation (Branchburg, NJ, USA), and Biomet Inc (Warsaw, IN, USA). One of the authors certifies that he (RTT), or a member of his immediate family, has received or may receive payments or benefits, during the study period, an amount of less than USD 10,000 from MAKO Surgical Corp, USD 10,000 to USD 100,000 from DePuy Orthopaedics, Inc, and less than USD 10,000 from Wright Medical Technology, Inc. One of the authors certifies that he (MJT), or a member of his immediate family, has received or may receive payments or benefits, during the study period, an amount of USD 1000 to USD 10,000 from DJO Global. One of the authors certifies that he (SRJ), or a member of his immediate family, has received or may receive payments or benefits, during the study period, an amount of USD 1000 to USD 10,000 from LifeCell Corporation. One of the authors certifies that he (RJS), or a member of his immediate family, has received or may receive payments or benefits, during the study period, an amount of USD 10,000 to USD 100,000 from Biomet Inc. All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request. *Clinical Orthopaedics and Related Research* neither advocates nor endorses the use of any treatment, drug, or device. Readers are

encouraged to always seek additional information, including FDA approval status, of any drug or device before clinical use. Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research. This work was performed at the Mayo Clinic, Rochester, MN, USA.

Electronic supplementary material The online version of this article (doi:10.1007/s11999-014-3612-z) contains supplementary material, which is available to authorized users.

C. C. Wyles
Mayo Medical School, Mayo Clinic, Rochester, MN, USA

S. R. Jacobson, N. V. Tran
Department of Plastic and Reconstructive Surgery, Mayo Clinic,
Rochester, MN, USA

M. J. Taunton, R. J. Sierra, R. T. Trousdale (✉)
Department of Orthopaedic Surgery, Mayo Clinic, 200 First
Street SW, Rochester, MN 55905, USA
e-mail: trousdale.robert@mayo.edu

surgery service. The perfusion of skin and soft tissue coverage was evaluated intraoperatively for all patients with the LA-ICGA system, and the information was used to guide wound management. Followup was at a mean of 9 months (range, 6–17 months), no patients were lost to followup, and the main study endpoint was uneventful healing of the surgical incision.

Results All seven closures went on to heal without necrosis. One patient, however, was subsequently revised for a deep periprosthetic infection 4 months after their knee reconstruction and underwent flap coverage at the time of that revision.

Conclusions Implementation of LA-ICGA provides an objective intraoperative assessment of soft tissue perfusion. This technology may help guide the surgeon's decisions about wound closure in real-time to accommodate the perfusion challenges unique to each patient. Specifically, patients with medical risk factors for poor perfusion or wound healing (such as diabetes, peripheral vascular disease, tobacco use, corticosteroid therapy, infection) or anatomical/surgical risk factors (ie, previous surgery about the reconstruction site, trauma wounds, or reconstruction of severe deformity) may benefit from objective intraoperative information regarding perfusion of the wound site. Furthermore, LA-ICGA could be used to prospectively evaluate the physiologic impact of different wound closure techniques.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Wound necrosis is a devastating complication after TKA. Risk factors for a wound problem include previous surgery about the knee as well as a host of medical comorbidities including diabetes mellitus, obesity, vascular disease, immunosuppressive therapy, smoking, and current or recent infection [20, 21]. Prevention is important in these patients and includes measures like proper choice of skin incision, gentle handling of the soft tissues, meticulous hemostasis, and wound closure without excessive tension [4]. All of these factors and preventive measures are based on the concept that skin perfusion must be robust to avoid a wound complication [17]. Clinical judgment based on visual inspection is the most common method for evaluating blood supply but is subjective and often unreliable [23]. A variety of technologies exist to assess blood supply clinically including Doppler or CT/MR angiography; however, none has gained acceptance as a pragmatic option in reconstructive surgery for use in the operating room [5].

Laser-assisted indocyanine green angiography (LA-ICGA) is a vascular imaging technology that can intraoperatively assess perfusion of the skin and soft tissues. This novel technology uses a plasma protein bound dye (ICG) and a camera unit that is calibrated to view the frequency emitted by the dye.

The real-time visualization of blood flow to skin and soft tissue made possible by LA-ICGA allows surgeons to tailor closure or coverage of the surgical site to meet the anticipated problem, potentially avoiding soft tissue reconstruction while preventing skin necrosis or wound breakdown after primary closures. LA-ICGA systems have existed for decades as a tool in ophthalmology and recently plastic surgery [23]. There are many features of this technology that make it appealing for evaluation of soft tissue perfusion in the surgical patient. Most importantly, it provides immediate qualitative and quantitative measurement of blood supply that can be correlated with successful wound healing [3, 8, 10, 14, 23]. The equipment needed to perform LA-ICGA is user-friendly and minimally disruptive to operative flow. Importantly, the ICG dye needed for assessment has an excellent safety profile and a short half-life allowing the surgeon multiple evaluations during a single procedure [5, 23]. Given the experience of other specialties, LA-ICGA has potential application in orthopaedic reconstruction for patients with higher risk of poor wound healing. However, to our knowledge, the use of LA-ICGA has never been described in an orthopaedic setting.

We therefore sought to evaluate perfusion borders and tension ischemia in a series of complex knee reconstructions to guide wound management.

Patients and Methods

This investigation is a series of seven selected patients who underwent complex knee reconstruction at the Mayo Clinic, Rochester, MN, USA, from 2011 to 2013; this represents all of the patients in whom the LA-ICGA system under study was used during that time period. All were considered high risk for wound necrosis or need of fasciocutaneous flap coverage as a result of scarring from previous procedures, presence of infection, or medical comorbidities. There were five males and two females with an age range of 51 to 68 years. Three patients in the group underwent complex primary TKA, two had resection of an infected TKA, and two underwent reimplantation of a previously infected TKA. Each patient in this group had multiple risk factors for wound healing complications, including prior surgery on the knee, previous wound breakdown, infections (active or prior), smoking, morbid obesity, and/or medical conditions associated with poor wound healing (Table 1).

LA-ICGA Imaging System

The SPY Elite[®] fluorescent imaging system (LifeCell Corporation, Branchburg, NJ, USA) was used in this series to assess perfusion of soft tissues about the knee in real-time. The LA-ICGA system consists of an imaging head that contains a

Table 1. Summary of cases and use of LA-ICGA technology

Case number	Age (years)	Sex	Comorbidities	Procedure and indication	Closure technique	Changes after LA-ICGA
1	55	Female	35-pack-year former smoker	Resection of infected TKA with cavitory defect over previous wound vac site	Primary closure with interrupted vertical mattress nylon sutures	Release of nylon sutures causing tension ischemia
2	66	Male	Chronic infection; morbid obesity; OSA; HTN; HLD severe leg lymphedema	Resection of infected TKA with previous flap coverage	Primary closure of previous flap	Preoperative incision mapping and elevation of previous flap
3	60	Male	PAD; DM; 45-pack-year former smoker; chronic infection; HTN; HLD; Stage III kidney disease	Reimplantation TKA postmultiple knee procedures with chronic infection	Primary closure with interrupted vertical mattress PDS sutures	Preoperative incision mapping and release of PDS sutures causing tension ischemia
4	58	Male	CAD with previous MI; HTN; HLD; OSA; morbid obesity	Reimplantation TKA postmultiple knee procedures with previous flap	Primary closure with interrupted vertical mattress PDS sutures	Preoperative incision mapping and release of PDS sutures causing tension ischemia
5	68	Female	Morbid obesity; HTN; HLD	Primary TKA with history of multiligament reconstruction and poor wound healing; recently infected THA	Skin flap after scar excision and 500 cc debulking of lipodystrophy; nylon vertical mattress sutures	Preoperative incision mapping and assessment of final closure perfusion
6	53	Male	Polymyalgia rheumatica; former smoker; HLD	Primary TKA with history of surgery for traumatic injury; polymyalgia rheumatica	Primary closure with running subcuticular Monocryl and skin staples	Preoperative incision mapping and assessment of final closure perfusion
7*	51	Male	Larsen syndrome; contralateral BKA; PAD; 30-pack-year former smoker; obesity; HTN; HLD	Primary TKA with history of multiple childhood knee procedures	Primary closure with vertical mattress nylon suture converted to running subcuticular Monocryl	Release of nylon sutures causing tension ischemia and conversion to running subcuticular Monocryl

* Required subsequent procedures for hematoma evacuation and deep periprosthetic infection; LA-ICGA = laser-assisted indocyanine green angiography; OSA = obstructive sleep apnea; HTN = hypertension; HLD = hyperlipidemia; PAD = peripheral artery disease; DM = diabetes mellitus; CAD = coronary artery disease; MI = myocardial infarction; BKA = below-knee amputation; PDS = polydioxanone suture.

charge-coupled device (CCD) camera, a laser light source, and a distance sensor. The laser operates at a power density of 40 mW/cm², well below the threshold of 200 mW/cm² where tissue damage can occur [6]. The CCD camera is attached to the mobile central processing unit by an arm with multiple points of articulation to allow positioning at a variety of angles (Fig. 1).

The LA-ICGA camera is calibrated to recognize the fluorescence of ICG, a water-soluble dye with a peak absorption of 800 to 810 nm in blood. ICG can be injected intravenously after it is reconstituted in sterile water. The dye rapidly binds to plasma proteins and is taken up almost exclusively by hepatic parenchymal cells with a half-life of approximately 5 minutes.

To obtain accurate measurements, all dressings must be removed from the skin before imaging. A sterile drape must be placed over the camera head and arm of the device to safely position it over the patient. The camera head is equipped with two red lasers that converge to a single point once optimal distance from the patient's skin has been achieved [12]. This feature ensures a high-quality image that is reproducible and standardized between cases.

Once the camera is in place and all tourniquets or blood pressure cuffs have been let down, the anesthesiologist can inject the ICG. The dye is prepared as a 25-mg powder that is reconstituted in 10 cc of sterile water for a final concentration of 2.5 mg/mL. A full dose of dye is 5 cc, allowing for two administrations per batch. The anesthesiologist pushes 5 cc of dye followed by a 10-cc saline flush after which time the operating room lights must be shut down immediately [12]. The ICG takes approximately 15 seconds to reach the knee. At this point, the camera can be left stationary or moved freely to assess perfusion of the soft tissues in real-time. The resultant image is scaled black and white with darker areas representing lower perfusion and brighter zones indicating higher perfusion. The LA-ICGA system used in this investigation is also capable of quantifying the brightness of up to 30 points simultaneously on a scale from 0 to 255 units, which enhances objectivity and reproducibility between cases. An example of imaging with the LA-ICGA can be seen in Video 1 (Available as supplemental material in the online version of CORR®).

Fig. 1 This is a photograph of the SPY Elite[®] system produced by LifeCell Corporation, which served as the LA-ICGA system for the investigation. Reproduced with permission of LifeCell Corporation and Novadaq Technologies (Bridgewater, NJ, USA).

For the purposes of this study, the qualitative images provided by the LA-ICGA system were used to determine (1) tissue viability of native skin and fasciocutaneous flaps; (2) perfusion barriers from previous surgery for planning new incisions; and (3) the presence of tension ischemia along the closure border (Table 1).

In patients with significant previous surgical scar or flap coverage, the information was used to assess perfusion about the knee before and during incision and exposure. Visualizing the soft tissue perfusion in real-time enabled more precise navigation around vulnerable areas to ensure that the most robustly perfused skin would be used for wound closure. At the conclusion of the procedures, LA-ICGA allowed for identification of poorly perfused zones. If areas of skin were receiving suboptimal blood flow, the closure was revised often by releasing sutures causing tension ischemia to the vulnerable tissue. Furthermore, LA-ICGA allowed for objective inspection of flap integrity to assess if the coverage was at risk of necrosis and breakdown.

Followup was at a mean of 9 months (range, 6–17 months), no patients were lost to followup, and the main study endpoint was uneventful healing of the surgical incision.

Results

Use of the LA-ICGA system altered management in each of the procedures in which we used it (Table 1). Preoperatively, the need for a flap was deemed highly likely; however, that intervention was successfully avoided for each patient. All seven patients, two of whose knees included previous flap coverage, had perfusion of final closure assessed to ensure tissue viability before concluding the procedure (Fig. 2). In five patients, LA-ICGA resulted in modification of a planned initial dissection (Fig. 3). In four patients, LA-ICGA revealed ischemia caused by undue tension at the time of wound closure relieved by modification of suture placement (Video 1, available as supplemental material in the online version of CORR[®]).

The incision of each patient healed without necrosis; however, one patient did require two subsequent procedures. The first was for evacuation of a hematoma 2 weeks after knee reconstruction and the second for deep periprosthetic infection 4 months after knee reconstruction. The patient underwent flap coverage at the time of the second procedure as a result of the extensive débridement required to successfully manage the infection.

Discussion

Wound necrosis presents a significant challenge in complex reconstructive knee surgery. Medical comorbidities, poor preprocedure planning, and improper intraoperative management of soft tissue can lead to a devastating result for the patient [4, 18]. Most surgeons rely on clinical judgment to assess tissue viability; however, this subjective valuation can be unreliable and lead to unexpected poor outcomes. LA-ICGA is a technology with a growing body of evidence, predominantly in the plastic surgery literature, that has demonstrated use as an objective system for analyzing soft tissue blood flow in real-time [1–3, 7–15, 19, 22]. Based on these reports, it seems possible that this system could have value in orthopaedic reconstruction. Nevertheless, to our knowledge, its use has never been reported in the orthopaedic literature. We therefore sought to evaluate perfusion borders and tension ischemia in a series of complex knee reconstructions to guide optimal wound management.

This study has multiple limitations, most notably that it is a small clinical series of selected patients. Our purpose is to present this technology simply as a proof of concept for potential use in orthopaedic surgery. The study should be interpreted only after acknowledging important sources of bias, notably patient selection and surgeon self-assessment of the clinical results. The cohort was chosen as a sample of convenience in patients in whom plastic surgery consultation believed the system could enhance surgical management.

Fig. 2A–C (A) This photograph depicts the LA-ICGA system after closure on a patient having reimplantation of a TKA after two-stage revision for infection. (B) A close photograph of the wound demonstrates the two lasers emitted by the camera head. The operator adjusts the distance of the camera from the wound until the two laser points converge to obtain a standardized and calibrated image. (C) This image depicts the visual output of the LA-ICGA system for

wound closure and surrounding soft tissue. Qualitative interpretation is achieved by understanding that bright areas are receiving more blood flow than darker areas. This image also demonstrates quantitative analysis where the operator chose an area of skin away from the incision to serve as the “100%” standard. A point was then selected close to the incision showing that perfusion is 67% of the standard point.

Unfamiliarity with the technology was the primary reason that only seven patients were accrued over the study period; however, positive early results are increasing the indications for the system at our institution, which we will report in future studies. Another issue relates to the surgeon evaluating his or her own work. Each operation was altered because of information provided by LA-ICGA, but the measureable benefits of the subsequent adjustments remain unclear. Furthermore, this series lacks a control group. Without a control group, we do not know the degree to which overall morbidity can be avoided (or might be added) through the use of this technology. All seven patients would have been candidates to receive a flap in our practice had we not used the LA-ICGA technology; however, it is worth noting that one of the seven underwent a flap as part of a later procedure related to infection 4 months after the operation performed in this series. Controlled trials are called for to rigorously assess the use of this technology in patient care. A final important limitation is that only qualitative data were assessed. The system used at our institution is also capable of quantifying perfusion in an absolute or relative fashion, which is a potential source of investigation for future studies.

Although not a limitation per se, it is important to note that this technology is relatively new. To our knowledge, the LA-ICGA system used in this investigation is the only FDA-approved device at this time. Variations of the technology are currently used in Japan and Europe that may enter the US market at some time in the future. The retail cost of our LA-ICGA system is USD 300,000 with rental and pay-per-use options available from the manufacturer. In addition, the retail cost of the custom-fit sterile drape kit and ICG dye is USD 795 per patient. Each practice will have to evaluate this economic impact within its own patient population.

In this series, LA-ICGA altered or determined management in each of the seven procedures performed. Contributions to each procedure included mapping of dissection and exposure to navigate perfusion barriers dictated by scar tissue and previous flap coverage, revision of wound closure to reestablish robust perfusion, and confirmation of global perfusion before concluding the procedure (Table 1). Although this series lacks a control group, the preoperative expectation was that each of these patients would require a flap at the time of wound closure or potentially shortly after

Fig. 3A–I (A–D) These right-sided preoperative AP and lateral radiographs with corresponding photographs are from a patient with Larsen's syndrome. This patient had multiple previous knee surgeries and presented with less than 20° of motion before undergoing TKA for pain and stiffness associated with this complex deformity. (E) An image captured by the LA-ICGA system displays wound closure of the patient after TKA. Note the severe tension ischemia along the incision created by the interrupted vertical mattress sutures on vulnerable soft tissue. Perfusion impairment to this degree would put

the patient at high risk for wound necrosis. (F) An image captured by the LA-ICGA system shows wound closure after revising the interrupted vertical mattress sutures with a running subcuticular closure. Global perfusion has been restored with significant improvement along the incision. (G) This postoperative image of the patient demonstrates a successfully corrected deformity and uncomplicated wound closure. (H–I) Postoperative AP and lateral radiographs demonstrate reconstruction with a hinge prosthesis.

their procedure if they experienced problems with healing. Despite this expectation, all seven wounds went on to heal successfully without necrosis or need for débridement and

flap coverage. One patient did experience a hematoma and deep periprosthetic infection, both of which required further operative intervention. The débridement of the

periprosthetic infection 4 months after knee reconstruction necessitated flap coverage for adequate closure. Our initial experience is consistent with that reported in numerous case series and prospective studies in the plastic surgery literature in which intraoperative, objective assessment of perfusion with LA-ICGA decreased rates of postoperative necrosis in comparison to clinical judgment alone [1–3, 5, 7, 8, 10, 11, 13, 14, 19, 23].

Future directions for study may include the use of LA-ICGA in a variety of orthopaedic reconstruction settings. Specifically, patients with medical risk factors for poor perfusion or wound healing (ie, diabetes, peripheral vascular disease, tobacco use, corticosteroid therapy, infection) or anatomical/surgical risk factors (ie, previous surgery about the reconstruction site, trauma wounds, or reconstruction of severe deformity) may benefit from objective intraoperative information regarding perfusion of the wound site. Although this series focused on the qualitative features of the technology, quantitation is also possible. The brightness of up to 30 points can be measured simultaneously on a scale from 0 to 255 units, which enhances objectivity and reproducibility between procedures. This feature could be used to prospectively evaluate the physiologic impact of different wound closure techniques.

As many practices are treating more complex revisions, in conjunction with the increasing emphasis in healthcare policy to avoid complications, this technology has the potential to be a useful tool in orthopaedic surgery moving forward. Importantly, the technology itself places the patient at little risk. The ICG dye is secreted into the bile and is not recirculated in the enterohepatic circulation to any large degree [15]. This mechanism of elimination makes the dye safe for use in patients with renal dysfunction. ICG is nontoxic and has only had 17 reported adverse reactions in 34 years, a rate of four in every 240,000 doses [16]. Although it is considered quite safe, the dye is contraindicated in patients with iodine allergies as a result of a 5% composition of sodium iodide. In summary, LA-ICGA is a tool that provides an option for objectively assessing and managing complex wound issues. This investigation is a proof of concept that the experience reported in plastic surgery may translate to orthopaedic reconstruction. Further prospective study with control groups will be needed to thoroughly evaluate this technology moving forward.

Acknowledgments We thank Karen Fasbender for her assistance in the preparation of the manuscript.

References

- Braun JD, Trinidad-Hernandez M, Perry D, Armstrong DG, Mills JL Sr. Early quantitative evaluation of indocyanine green angiography in patients with critical limb ischemia. *J Vasc Surg.* 2013;57:1213–1218.
- Brunworth LS, Samson MC, Newman MI, Ramirez JR. Nipple-areola complex evaluation in long pedicled breast reductions with real-time fluorescent videoangiography. *Plast Reconstr Surg.* 2011;128:585–586; author reply 586–587.
- Chatterjee A, Krishnan NM, Van Vliet MM, Powell SG, Rosen JM, Ridgway EB. A comparison of free autologous breast reconstruction with and without the use of laser-assisted indocyanine green angiography: a cost-effectiveness analysis. *Plast Reconstr Surg.* 2013;131:693e–701e.
- Dennis DA. Wound complications in total knee arthroplasty. *Orthopedics.* 1997;20:837–840.
- Gurtner GC, Jones GE, Neligan PC, Newman MI, Phillips BT, Sacks JM, Zenn MR. Intraoperative laser angiography using the SPY system: review of the literature and recommendations for use. *Ann Surg Innov Res.* 2013;7:1.
- Lepow B, Perry D, Armstrong D. The use of SPY intra-operative vascular angiography as a predictor of wound healing. *Podiatry Management.* 2011;8:141–148.
- Losken A, Zenn MR, Hammel JA, Walsh MW, Carlson GW. Assessment of zonal perfusion using intraoperative angiography during abdominal flap breast reconstruction. *Plast Reconstr Surg.* 2012;129:618e–624e.
- Mohebbi J, Gottlieb LJ, Agarwal JP. Further validation for use of the retrograde limb of the internal mammary vein in deep inferior epigastric perforator flap breast reconstruction using laser-assisted indocyanine green angiography. *J Reconstr Microsurg.* 2010;26:131–135.
- Murray JD, Jones GE, Elwood ET, Whitty LA, Garcia C. Fluorescent intraoperative tissue angiography with indocyanine green: evaluation of nipple-areola vascularity during breast reduction surgery. *Plast Reconstr Surg.* 2010;126:33e–34e.
- Newman MI, Samson MC. The application of laser-assisted indocyanine green fluorescent dye angiography in microsurgical breast reconstruction. *J Reconstr Microsurg.* 2009;25:21–26.
- Newman MI, Samson MC, Tamburrino JF, Swartz KA. Intraoperative laser-assisted indocyanine green angiography for the evaluation of mastectomy flaps in immediate breast reconstruction. *J Reconstr Microsurg.* 2010;26:487–492.
- Novadaq. *The SPY Elite Intraoperative Perfusion Assessment System Operator's Manual, November 2011013-50001-001, rev C.* Richmond, British Columbia, Canada: Novadaq Technologies; 2008.
- Perry D, Bharara M, Armstrong DG, Mills J. Intraoperative fluorescence vascular angiography: during tibial bypass. *J Diabetes Sci Technol.* 2012;6:204–208.
- Pestana IA, Coan B, Erdmann D, Marcus J, Levin LS, Zenn MR. Early experience with fluorescent angiography in free-tissue transfer reconstruction. *Plast Reconstr Surg.* 2009;123:1239–1244.
- Prompers L, Schaper N, Apelqvist J, Edmonds M, Jude E, Mauricio D, Uccioli L, Urbancic V, Bakker K, Holstein P, Jirkovska A, Piaggese A, Ragnarson-Tennvall G, Reike H, Spraul M, Van Acker K, Van Baal J, Van Merode F, Ferreira I, Huijberts M. Prediction of outcome in individuals with diabetic foot ulcers: focus on the differences between individuals with and without peripheral arterial disease. The EURODIAB Study. *Diabetologia.* 2008;51:747–755.
- Reuthebuch O, Haussler A, Genoni M, Tavakoli R, Odavic D, Kadner A, Turina M. Novadaq SPY: intraoperative quality assessment in off-pump coronary artery bypass grafting. *Chest.* 2004;125:418–424.
- Ries MD. Skin necrosis after total knee arthroplasty. *J Arthroplasty.* 2002;17:74–77.

18. Ries MD, Bozic KJ. Medial gastrocnemius flap coverage for treatment of skin necrosis after total knee arthroplasty. *Clin Orthop Relat Res.* 2006;446:186–192.
19. Tan BK, Newman MI, Swartz KA, Samson MC. Subfascial perforator dissection for DIEP flap harvest. *Plast Reconstr Surg.* 2009;124:1001–1002; author reply 1002.
20. Vince K, Chivas D, Droll KP. Wound complications after total knee arthroplasty. *J Arthroplasty.* 2007;22:39–44.
21. Vince KG, Abdeen A. Wound problems in total knee arthroplasty. *Clin Orthop Relat Res.* 2006;452:88–90.
22. Woodard CR, Most SP. Intraoperative angiography using laser-assisted indocyanine green imaging to map perfusion of forehead flaps. *Arch Facial Plast Surg.* 2012;14:263–269.
23. Zenn MR. Fluorescent angiography. *Clin Plast Surg.* 2011;38:293–300.