



The Mayo Clinic Total Wrist Implant: A New Era of Restoring Function Through Replacement

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in Patients
With Chronic
Kidney Diseases

In 1972, the Mayo Clinic Department of Orthopedic Surgery opened a new frontier of diagnosis and treatment of wrist injury with the publication of a classic paper by Ronald L. Linscheid, MD, and James H. Dobyns, MD. In it, the investigators set forth a framework for understanding carpal instability that influenced many subsequent therapeutic wrist advances, leading ultimately to wrist joint replacement.

Mayo's novel conceptualization of wrist instability related to carpal bone malalignment, ligament laxity, and secondary arthritis helped pave the way for the emergence of advanced prosthetics.

Restoring Anatomical Integrity

Before the advent of wrist joint replacement, orthopedic surgeons relieved wrist pain and dysfunction from posttraumatic arthritis, osteoarthritis, and rheumatoid arthritis by modifying bone, such as removing the trapezium or the distal end of the

ulna, or by fusing the wrist bones. But much of the joint function was lost with such procedures. The important principle that Mayo Clinic contributed was the idea that prostheses, such as the total wrist, distal ulna, and thumb joint, usually can closely restore the normal anatomy—and anatomical correctness and joint integrity—to optimize function (Figure 1). Biomechanically and clinically, wrist replacement tends to be a much better solution than cutting away

Points That Influenced Many Subsequent Therapeutic Advances

- Before wrist joint replacement became widely used, orthopedic surgeons relieved pain and dysfunction from osteoarthritis and rheumatoid arthritis by removing or fusing bones.
- Mayo Clinic's novel conceptualization of wrist instability related to carpal bone malalignment, ligament laxity, and secondary arthritis helped pave the way for the emergence of advanced wrist and hand prosthetics.
- Prostheses, such as the total wrist, distal ulna, and thumb joint, usually can optimize function through closely restoring the normal anatomy and joint integrity.

bone or stiffening the bones (wrist fusion) at the expense of the joint's structural design.

The Mayo Method: Engineers and Orthopedists

Specialists across many disciplines contributed to Mayo's wrist advances, including earlier work on the lower extremities. In 1969, a Mayo Clinic orthopedic surgeon performed the first US Food and Drug Administration–approved total hip replacement. Mayo's work on joint replacement of the hip, knee, shoulder, and elbow helped to refine the collaborative research method and culture between clinical-surgical care and bioengineering.

The team approach of basing investigative ideas on orthopedic anatomy and biomechanics continues today at Mayo Clinic. A collaborative team of biomechanical engineers and orthopedic specialists translates clinical orthopedic problems

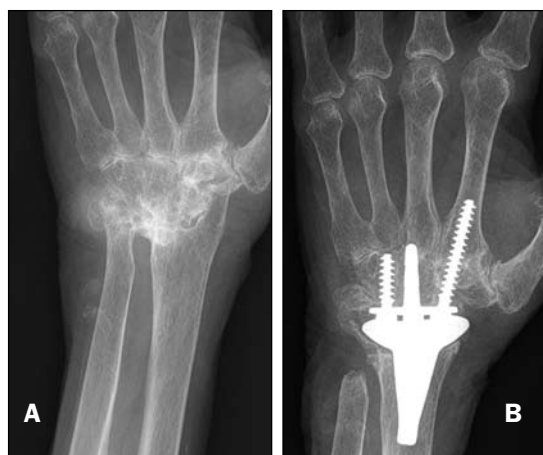


Figure 1. Treatment of advanced rheumatoid arthritis of the wrist. A, Treatment with total wrist replacement. B, Note the distal rigid fixation of the implant to the carpus and second and third metacarpals, excision of the distal ulna, and press-fit fixation of the distal radial component.

into mechanical problems with engineering solutions—and then translates them back into the clinical context and applies them to patient care. The alliance of these 2 cultures has enabled Mayo Clinic to work more easily with production companies to put ideas into practice. The endeavor to follow this model has led to great advances in hand and wrist surgery during the past 10 to 15 years.

Twenty Years of Funded Hand and Wrist Research

The collaboration with engineers led to some 20 years of research, supported by the National Institutes of Health, investigating biomechanical and kinematic forces in the hand and wrist of



Figure 2. Wear-testing machine designed by the Mayo Clinic biomechanical orthopedics laboratory to investigate wear characteristics.

Pioneering Practice

Major Mayo Wrist Milestones

- **1970s:** Landmark paper in 1972 by Linscheid and Dobyns revealing new insights into instability
- **1980s:** First Mayo International Wrist Workshop leading to ongoing Mayo wrist course presentation every 3 years
- **1990s:** Continued development and refinement of total wrist implant and related small-joint components of metal and plastic for surface replacement implants of proximal interphalangeal and metacarpophalangeal joints
- **2000s:** Introduction in 2006 of instrumentation to facilitate correct anatomical placement of a total wrist implant; development of a metallic ulnar-head implant for patients with unstable forearms secondary to excision of an arthritic ulnar head

healthy patients, of patients with disease, and of cadavers and anatomical models. The investigations included wear-force characteristics evaluated in a custom-designed wear-testing machine that simulated the loading and motion of the wrist from flexion, extension, radioulnar deviation, and axial rotation (Figure 2).

According to Mayo researchers and surgeons involved in this effort, solutions did not come right away, partly because the wrist is different from other joints. While the hip is a ball and socket joint, the wrist is more like a Rubik's cube with 8 bones in it. But over time, their work all came together in this new vision of wrist replacement, which now greatly benefits patients with wrist instability.

Continued collaborative research between Mayo wrist surgeons and biomechanical engineers may provide for partial wrist replacement technology as the wave of the future.

Hybrid Approach to Coronary Artery Disease

The options for revascularization in patients with coronary artery disease (CAD) increasingly appear to be in direct competition with each other. The long-established role of coronary artery bypass graft (CABG) surgery is being challenged by the outcomes achieved with percutaneous coronary intervention (PCI) deploying drug-eluting stents (DESs). The ongoing SYNTAX (Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery) Trial comparing CABG surgery with PCI and DES for patients with multivessel CAD

or left main CAD has shown, in early follow-up, a similar early survival in both treatment groups. The investigators recognize the limitations of PCI in patients with complex anatomy in the coronary lesions (eg, calcification, sequential lesions, bifurcation lesions) and the trial suggests a more limited durability of PCI.

A better approach to CAD may be available in this evolving field. From the patient's perspective, it is not a question of 1 technique (provided by 1 type of specialist) "winning out" over another technique (provided by another

type of specialist). Rather, patients expect the best treatment approach based on their coronary disease, anatomy, and comorbid conditions, with the goal of a good outcome while minimizing risk and allowing early return to normal activities. According to Mayo Clinic specialists, a hybrid approach that combines both the advantages of CABG and the advantages of PCI might be the optimal treatment available for CAD today.

Advantages of PCI

PCI has the obvious advantages of being minimally invasive with minimal patient discomfort and allowing early return to normal activity. The approach also may minimize risk of some potential complications. The results of the SYN-TAX Trial have suggested that the risk of stroke with PCI is less than with CABG, although the 2 treatment groups received different antiplatelet medical therapy during the trial.

In the past, concern existed that the durability of PCI may be less than that of CABG, with increased need for later interventions. Although DESs have not been compared directly with saphenous vein graft (SVG) conduits, current stents may provide durability that is at least as good as SVG conduits. Indeed, the 1-year patency rate of SVG conduits is probably about 85% to 90%; the patency rate of DESs may be slightly better than 90%. Data on follow-up with actual angiography are limited, so this conclusion is inferred from data on the need for reintervention, which seems to be reasonably accurate. Finally, new technology and evolving skills of interventional cardiologists have allowed a percutaneous approach to multivessel disease, left main disease, and more complex coronary lesions.

Advantages of CABG

The clear advantage and most important aspect of CABG is the use of the left internal mammary artery (LIMA) as a bypass graft to the left anterior descending coronary artery (LAD). The LIMA-to-LAD graft has been shown to be crucial for optimal long-term survival. If the LIMA graft is patent early, it will probably be patent indefinitely, and 10- and 20-year patency rates exceed 90%. Bypass grafts treat the culprit lesions but also provide prophylaxis against future proximal lesions and protect the entire zone of vulnerable myocardium in diffusely unstable coronary endothelium. The complexity of the coronary lesions is not as much a factor in the LIMA graft as in PCI because bypass grafts can be placed around any type of proximal lesion.

Points to Remember

- A hybrid approach that combines the advantages of a coronary artery bypass graft using a minimally invasive approach with the advantages of percutaneous coronary intervention (PCI) might be the optimal approach available for treating coronary artery disease today.
- A single bypass graft of the left internal mammary artery to the left anterior descending coronary artery (LAD) can be performed in a minimally invasive manner and off-pump. The approach is called a *minimally invasive direct coronary artery bypass* (MIDCAB).
- A hybrid approach involves a MIDCAB, preceded or followed by PCI of the non-LAD lesions with drug-eluting stents. This approach does not require a sternotomy or cardiopulmonary bypass and provides complete revascularization in a minimally invasive manner.
- The hybrid technique may be either a 2-stage approach with the MIDCAB preceded or followed by PCI or a single-stage procedure in which all steps are performed during a single surgical session.

CABG can be performed off-pump, and the LIMA-to-LAD anastomosis lends itself to an off-pump approach because the heart position does not need to be manipulated excessively. Although controversial, an off-pump approach to CABG probably does reduce the risk of renal insufficiency, pulmonary injury, and bleeding. In addition, many studies have shown a reduced hospital stay with off-pump CABG. Single LIMA-to-LAD grafting performed off-pump does not require manipulation of the aorta, and thus the risk of stroke is minimized.

A single bypass graft of the LIMA to the LAD can be performed in a minimally invasive manner and off-pump. The approach is called *minimally invasive direct coronary artery bypass* (MIDCAB) and involves mobilization of the LIMA with a thoracoscopic or robotic technique and direct anastomosis of the LIMA to the LAD through a minimally invasive, 4- to 5-cm left anterior thoracotomy. After this procedure, patients can return to work early, the result is

Box. Comparison Between Single-Stage and 2-Stage Hybrid Approaches

Single-stage hybrid approach

- This approach requires a specialized operating room containing the fluoroscopic equipment necessary for percutaneous coronary intervention (PCI).
- The approach results in better patient satisfaction and, potentially, a reduced hospital stay.

Two-stage hybrid approach

- Antiplatelet therapy can be timed to reduce bleeding at the minimally invasive direct coronary artery bypass and allow adequate antiplatelet therapy dosing for PCI.
- A functioning left internal mammary artery-to-left anterior descending coronary artery graft allows subsequent PCI to be performed safely for ostial circumflex lesions, complex left main lesions, and perhaps other lesions.
- The 2-stage hybrid approach eliminates the need for the costly use of a specialized operating room and also allows PCI to be performed in a catheterization laboratory with fully available functionality.
- The athlete can follow up with his or her physician within 24 to 48 hours for a physical examination and symptom evaluation, as well as additional cognitive testing.

acceptable cosmetically, and length of hospital stay usually is short.

Hybrid Approach to Coronary Revascularization

A hybrid approach to coronary revascularization combines the advantages of CABG and PCI. The hybrid approach involves a MIDCAB, which provides the patient with the benefits of a LIMA-to-LAD bypass graft, performed in a minimally invasive manner with thoracoscopic or robotic mobilization of the LIMA and a small left anterior thoracotomy for the LIMA-to-LAD anastomosis. This procedure is either preceded by or followed by PCI of the non-LAD lesions with DESs. The patient avoids the need for sternotomy and cardiopulmonary bypass and has complete revascularization in a minimally invasive manner, maintaining the advantage of the LIMA-to-LAD bypass graft.

The hybrid technique may be either a 2-stage approach with the MIDCAB preceded by or followed by PCI or a single-stage procedure in which all steps are performed during a sole surgical session (see Box for a comparison of these 2 procedures).

Patient Selection

Patients with multivessel CAD, including LAD disease, a graftable LAD, and non-LAD lesions amenable to PCI, could be considered for the hybrid approach. Candidates could include patients who normally might not be considered for PCI, including those with complex or distal left main disease, ostial LAD or circumflex disease, and complex or multiple LAD lesions. Other patients who might benefit include

patients who have minimal conduits available for CABG and patients who are at increased risk due to advanced age, frailty, renal insufficiency, diabetes mellitus, and aortic calcification or atherosclerosis.

The hybrid approach is contraindicated in patients who are not good candidates for MIDCAB, including those with a nongraftable or deep intramyocardial LAD. Additional possible contraindications include previous left thoracotomy or left subclavian artery stenosis, inability to tolerate single-lung ventilation, and severe obesity. A hybrid approach is also contraindicated in patients who are not candidates for PCI, possibly including those with chronic total coronary artery occlusions, calcified or complex lesions in the non-LADs, and limited vascular access for PCI.

Outcomes of a Hybrid Approach to Coronary Revascularization

A few research groups have reported outcomes in a limited number of patients who received a hybrid approach. All studies are small and non-randomized but have shown safety and efficacy. Long-term outcomes are unknown.

Conclusions

The hybrid approach to revascularization in CAD is promising. For low-risk patients, it allows the benefit of a minimally invasive approach along with the long-term benefit of the LIMA-to-LAD bypass. Potential early return to work and reduced need for further intervention may contribute to cost-effectiveness in this patient group over time, but those advantages are speculative. Selected high-risk patients may

benefit from a minimally invasive approach. Complex LAD lesions are bypassed readily but may be difficult to treat with PCI. LIMA-to-LAD bypass graft allows a percutaneous approach to complex left main and ostial circumflex lesions with more safety. DESs in non-LAD lesions are likely to be at least as durable as SVG conduits, at least in the medium term.

A 2-stage approach does not require a specialized operating room with fluoroscopic

capabilities. However, the approach does require collaboration between surgery and cardiology specialists and willingness on the part of surgeons to continue to adapt to less invasive techniques. Although clinical data on outcomes are limited at this time, improvements in technology and the changing population with CAD will increasingly make the hybrid approach to treatment the optimal choice for many patients.

Treatment of Dyslipidemia in Patients With Chronic Kidney Diseases

Cardiovascular events are the number 1 cause of death in patients with chronic kidney disease (CKD). These patients have an increase in their blood concentrations of low-density lipoprotein cholesterol (LDL-C), non-high-density lipoprotein cholesterol, small dense LDL-C, modified LDL-C, lipoprotein(a), and C-reactive protein. The increase in blood triglyceride concentration and the decrease in high-density lipoprotein cholesterol (HDL-C) concentration are more marked in patients

Box. Secondary Causes of Dyslipidemia in Patients With Chronic Kidney Disease

Medical conditions

- Alcohol consumption
- Diabetes mellitus
- Hypothyroidism
- Liver disease
- Nephrotic syndrome

Medications

- Androgens and estrogens
- Anticonvulsants
- β -Adrenergic inhibitors
- Corticosteroids
- Cyclosporine
- Diuretics
- Highly active antiretroviral therapy (HAART)
- Sirolimus
- 13-*cis*-retinoic acid

Points to Remember

- The Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommend dyslipidemia evaluation of all patients with chronic kidney disease (CKD).
- Large randomized placebo-controlled trials have shown that treatment with statins caused statistically significant reductions in all-cause and cardiovascular mortality rates in patients with mild to moderate CKD.
- More studies are required to establish the role of statins in patients with stage 5 CKD and in renal transplant recipients.
- The KDOQI guidelines recommend treatment with a fibrate or niacin when the blood triglycerides concentration is 500 mg/dL or greater and the patient has no response to therapeutic lifestyle interventions.

with CKD who also have nephrotic syndrome.

In 2003, the National Kidney Foundation published the Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines, which included recommendations for assessment and treatment of dyslipidemia in patients with CKDs. The KDOQI guidelines recommend evaluation of all patients with CKD for dyslipidemia through testing of fasting blood concentrations of total cholesterol, LDL-C, HDL-C, and triglycerides. For patients with stage 5 CKD, the lipid panel

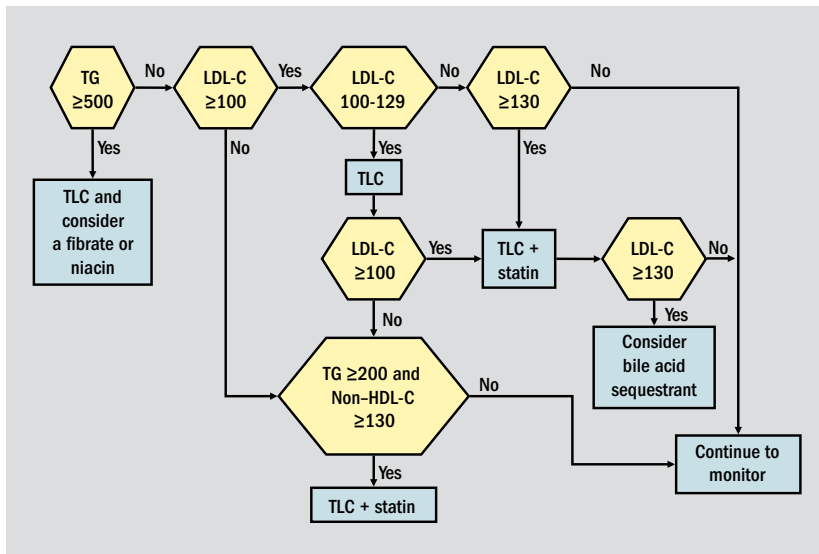


Figure. Approach to the treatment of dyslipidemia in patients with chronic kidney disease. Units for cholesterol and triglycerides are mg/dL. HDL-C indicates high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; TLC, therapeutic lifestyle changes. Adapted from Kidney Disease Outcomes Quality Initiative (K/DOQI) Group. K/DOQI clinical practice guidelines for management of dyslipidemias in patients with kidney disease. *Am J Kidney Dis.* 2003 Apr;41(4 Suppl 3):I-IV, S1-91. Used with permission. (From *EndoUpdate* 5(1) 2010, p 2.)

mg/dL or greater and the patient has no response to therapeutic lifestyle interventions. The targets and treatment strategies for blood LDL-C concentrations for patients with CKD are not different from those for patients without CKD.

Patients with severe CKD were not included in the large randomized placebo-controlled trials that were designed to assess the effects of 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors (statins). However, secondary analyses of the data from patients with mild to moderate CKD showed that treatment with statins caused statistically significant reductions in all-cause and cardiovascular mortality rates. These benefits seemed to be at least as remarkable as those found in the patients without CKD. In addition, statins have been shown to be safe for patients with CKD, and they do not impact renal function. Yet, results from 2 large trials revealed that statin use did not decrease cardiovascular events or death in patients receiving hemodialysis, despite declines in blood lipid concentrations similar to those seen in patients with mild to moderate CKD. In addition, gemfibrozil use for patients with mild to moderate CKD has not been shown to have an impact on major cardiovascular events or overall mortality rate.

Only 1 large study has addressed the cardiovascular and survival benefits of statin treatment in renal transplant recipients. A clinically significant reduction in hyperlipidemia, similar to that seen in patients with mild to moderate CKD, was observed in that study. Although there was a nonsignificant trend for a reduction in cardiovascular events, there was no impact on mortality outcomes. However, potential effects of statin treatment on prevention of organ rejection are under investigation.

Screening for and treatment of dyslipidemia in patients with mild to moderate kidney disease appear to have fair evidence (Table 2). However, statin use for patients receiving hemodialysis and for renal transplant recipients does not have a strong evidence base. More studies are required to establish the role of statins in patients with stage 5 CKD and for renal transplant recipients.

Table 1. Therapeutic Goals for Dyslipidemia in Adults With Chronic Kidney Disease

Lipid Concentration	Goal	Initial Treatment	If Not at Goal After Initial Treatment	Alternative Additional Treatment
TG ≥500 mg/dL	TG <500 mg/dL	TLC	Add fibrate or niacin	Add fibrate or niacin
LDL-C 100-129 mg/dL	LDL-C <100 mg/dL	TLC	Add low-dose statin	Add bile acid sequestrants or niacin
LDL-C ≥130 mg/dL	LDL-C <100 mg/dL	TLC + low-dose statin	↑ to maximum-dose statin	Add bile acid sequestrants or niacin
TG ≥200 mg/dL and non-HDL-C ≥130 mg/dL	Non-HDL-C <130 mg/dL	TLC + low-dose statin	↑ to maximum-dose statin	Add fibrate or niacin

Abbreviations: HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; TLC, therapeutic lifestyle changes. Adapted from Kidney Disease Outcomes Quality Initiative (K/DOQI) Group. K/DOQI clinical practice guidelines for management of dyslipidemias in patients with kidney disease. *Am J Kidney Dis* 2003 Apr;41(4 Suppl 3):I-IV, S1-91. Used with permission.

should be performed at presentation, annually thereafter, and at 2 to 3 months after every change in treatment. In addition, patients with dyslipidemia should be evaluated for possible secondary causes of the condition (Box).

The KDOQI guidelines (Figure and Table 1) recommend treatment with a fibrate or niacin when the blood triglycerides concentration is 500

Table 2. Summary of Effects of Statins (vs No Treatment) in Patients With CKD and Renal Transplant Recipients

Lipid Status or Risk Factor	Patient Subgroups ^a		
	CKD Without Dialysis	CKD With Dialysis	Renal Transplant
Decrease in total cholesterol, mg/dL	~42	~43	~42
Decrease in LDL-C, mg/dL	~42	~43	~46
Increase in HDL-C, mg/dL	~1.3	NS	NS
Decrease in triglycerides, mg/dL	~29	~24	~25
Risk reduction for all-cause death, %	~19	NS	NS
Risk reduction for CV death, %	~20	NS	NS
Risk reduction for nonfatal CV events, %	~25	NS	NS
Risk of increased creatine kinase, %	NS	NS	NS
Risk of increased liver function test results, %	NS	NS	NS
Risk of withdrawal due to adverse events, %	NS	NS	NS

Abbreviations: CKD, chronic kidney disease; CV, cardiovascular; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NS, not significant.

^a Data summarized from Navaneethan SD, Pansini F, Perkovic V, et al. HMG CoA reductase inhibitors (statins) for people with chronic kidney disease not requiring dialysis. *Cochrane Database Syst Rev* 2009 Apr 15;(2):CD007784; Navaneethan SD, Nigwekar SU, Perkovic V, et al. HMG CoA reductase inhibitors (statins) for dialysis patients. *Cochrane Database Syst Rev* 2009 Jul 8;(3):CD004289; Navaneethan SD, Perkovic V, Johnson DW, et al. HMG CoA reductase inhibitors (statins) for kidney transplant recipients. *Cochrane Database Syst Rev* 2009 Apr 15;(2):CD005019.

Education Opportunities

Pediatric Fundamental Critical Care Support (FCCS) Course

September 20-21, 2011

Mayo Clinic, Rochester, MN

This 2-day course provides an exposure to the basic principles of pediatric critical care. Its main goals are to enhance the ability of the primary care practitioner in performing the initial assessment of critically ill pediatric patients and to augment their skills in managing and stabilizing patients in anticipation of transport to a tertiary care center.

Internal Medicine Review for Nurse Practitioners, Physician Assistants and Primary Care Physicians

September 26-28, 2011

Mayo Clinic, Rochester, MN

This annual interdisciplinary course offers participants an overview of current topics in internal medicine, including interactive case studies through an automated audience response system. Interdisciplinary speakers present diverse clinical topics applicable to nurse practitioners, physician assistants, and primary care physicians in practice settings.

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Education Opportunity

An Overview of Perioperative Medicine 2011: From Outpatient Preoperative Assessment to Inpatient Postoperative Care

October 12-15, 2011

Swissotel, Chicago, IL

This course updates general internists, internist-subspecialists, family medicine physicians, anesthesiologists, surgeons, and other health care providers on perioperative assessment and management. It focuses on the practical, clinical side of preoperative assessment and postoperative management and features a collaborative faculty of multispecialty experts in perioperative medicine from both Mayo Clinic and Jefferson Medical College.

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