

Carla M. Nester MD, MSA, FASN

Jean E. Robillard MD, Chair in Pediatric Nephrology | Adult and Pediatric Nephrology Director- Rare Renal Disease Clinic | Director- Division of Pediatric Nephrology, Dialysis, and Transplantation | Associate Director- Molecular Otolaryngology and Renal Research Laboratories | University of Iowa Hospitals and Clinics



Richard JH Smith, MD

Director- Molecular Otolaryngology and Renal Research Laboratories | Director- The Iowa Institute of Human Genetics | Professor of Internal Medicine and Pediatrics, Divisions of Nephrology, Otolaryngology, Molecular Physiology & Biophysics | Sterba Hearing Research Professor | Vice Chair - Department of Otolaryngology



Rebecca Franklin, RN, BSN

C3G Clinical Nurse Coordinator |Molecular Otolaryngology and Renal Research Laboratories (MORL) | 5292 Carver Biomedical Research Building PH: 319-467-4824 / FX: 319-384-9616



Tina Liu, BA

C3G Research Associate | Molecular Otolaryngology and Renal Research Laboratories (MORL) | Carver Biomedical Research Building



Amy Weaver

Administrative Services Coordinator | Molecular Otolaryngology and Renal Research Laboratories (MORL) | Carver Biomedical Research Building



Whitney Farmer



Andrew Rauenbuehler



Tiana Washington

C3G Research Support Students
Molecular Otolaryngology and Renal Research Laboratories (MORL) | Carver Biomedical Research Building

C3 GLOMERULOPATHY



MORL
Molecular Otolaryngology & Renal Research Laboratories

IOWA HEALTH CARE
Stead Family Children's Hospital

This pamphlet was made possible through the generous donations of rare disease family members.

C3 Glomerulopathy (C3G)

C3G is an ultra-rare kidney disease that most frequently affects children and young adults. Many times, the first signs of C3G are blood and/or protein in the urine found during a routine doctor's appointment or while a patient is being evaluated for high blood pressure. Other people experience more severe symptoms, such as swelling and abnormal lab values, including elevated creatinine and low albumin and C3 levels. Severe fatigue is also a common patient complaint.

C3G is caused by uncontrolled activity of an immune pathway called the alternative pathway (AP). This is why C3G is often found for the first time after an infection, when the immune system has been activated. Once activated, the immune system of the C3G patient cannot shut down properly, and the excess activity produces many complement breakdown products that deposit in the kidneys and cause disease. Excess complement activity is also why many patients with C3G have a low blood C3 level; C3 is being "used up" because of the increased activity. We call this excess activity "dysregulation" of the alternative pathway of complement.

Our goal is to determine what causes each person's C3G. We refer to this as the "driver of disease". The driver of C3G is most often related to autoimmune reasons (approximately 65%), and less often to genetic causes (approximately 20%). Autoimmune proteins called nephritic factors (C3 Nef, C5 Nef and/or C4 Nef) are most commonly identified. These proteins bind to complement proteins and alter the normal function of the complement system. This change is also referred to as "dysregulation". Other autoantibodies against complement proteins may also be present. We do not know why these proteins are produced.

The diagnosis of C3G is made by performing a kidney biopsy. In C3G, the immunofluorescence (IF) portion of the kidney biopsy demonstrates dominant C3 staining, with C3 deposits that are at least two times greater than any other immune reactant. The biopsy may also show increased cellularity on light microscopy (LM), referred to as "proliferation."

Other diseases, such as post-infectious glomerulonephritis (PIGN), may have a biopsy pattern that appears identical to that of C3G. Therefore, it may be difficult to diagnose C3G immediately. In many cases, we monitor a patient's laboratory values, including C3 and urine protein and blood measurements, for three months to determine whether C3G is present.

There are two types of C3G: C3 Glomerulonephritis (C3GN) and Dense Deposit Disease (DDD).

Outcomes/Treatment

While significant progress has been made in understanding the natural history of C3G, research is ongoing to further characterize the disease. Based on current knowledge, C3G frequently leads to chronic kidney disease. Up to 50% of patients progress to end stage kidney disease within 10 years of diagnosis. However, these outcomes may improve with the use of new complement-targeting therapies that have recently completed clinical trials.

C3G can reappear in a transplanted kidney, with biopsy findings consistent with C3G occurring in up to 90% of patients. However, we do not consider this true disease recurrence unless there is evidence of active disease, including proliferation on biopsy, protein and blood in the urine, rising creatinine levels, or decreasing C3 levels. This definition of recurrence may evolve as our understanding of the disease continues to improve.

Until recently, treatment for C3G was primarily supportive, with an escalation to standard immunosuppression based on the urine protein levels and/or changes in the creatinine. Now physicians have more choices. Two new FDA-approved treatments are now available.

Iptacopan, approved for individuals 18 years old and older, works by binding to Factor B of the AP. It regulates the cleavage of C3, the accumulation of downstream effectors, and amplification of the alternative pathway.

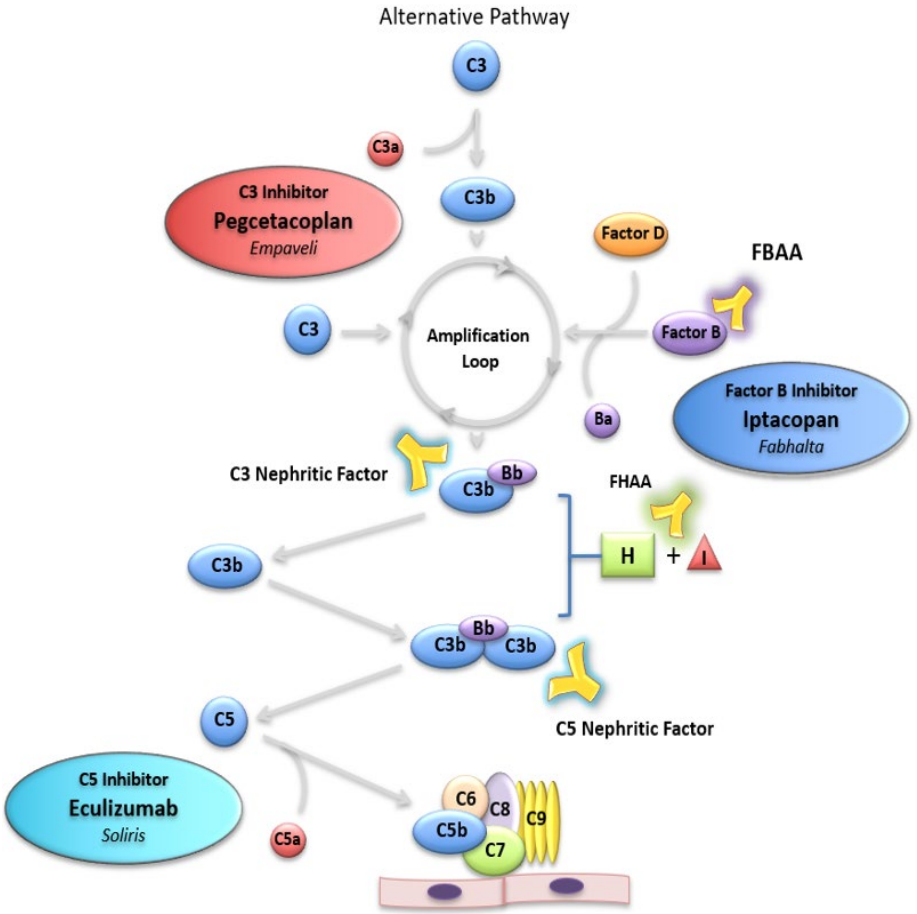
Pegcetacoplan, approved for individuals 12 years old and older, is a C3 and C3b inhibitor that blocks the cleavage of C3, reducing C3 fragment deposition, the amplification of the alternative pathway, and the impact of downstream effectors.

The new treatment approach for patients with C3G will need to be individualized.

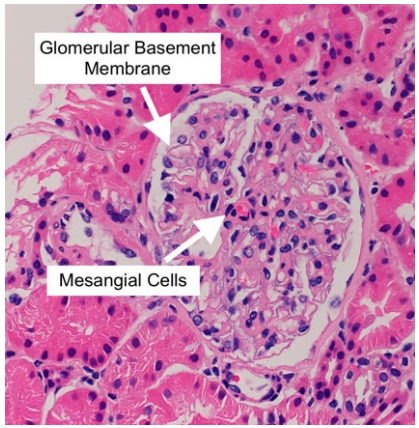
All patients require supportive care. The sequence of next steps is changing rapidly, and full confirmation of treatment guidelines is pending. For many patients, the approach may include one of the new agents as first-line therapy (after complete vaccination)

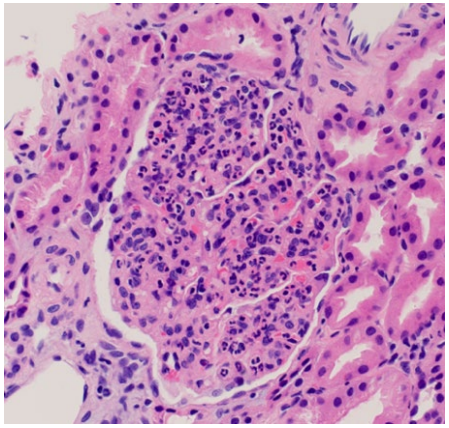
Complement Cascade

Abnormalities in the alternative pathway of complement in C3G patients may be detected in the laboratory. The figure below displays the relative location of these proteins. Included in this figure for reference are the proteins that may be blocked by the new therapeutics

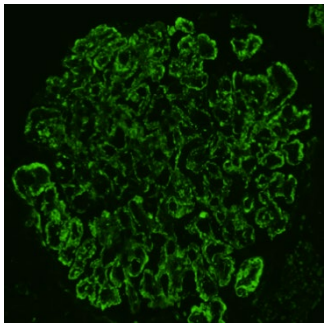


Pathology



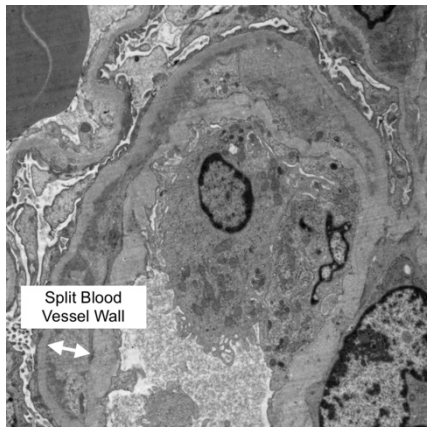


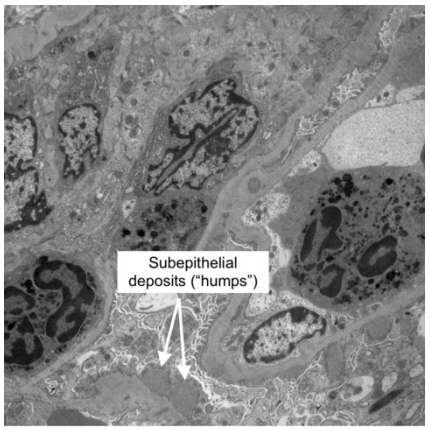
Light Microscopy (LM) appearance of a glomerulus
Normal glomerulus (left): Open, thin-walled blood vessels, no extra mesangial cells.
C3G glomerulus (right): Blood vessel walls are thickened and often consumed by deposits and contain many more cells (*proliferative, hypercellular*; purple dots are cell nuclei).



Immunofluorescence (IF)
Left: Typical appearance of bright green C3 deposits on a C3G biopsy specimen.

Electron Microscopy
Below Left: Split blood vessel wall basement membrane (MPGN pattern)
Below Right: Subepithelial humps – seen in C3G and post infectious glomerulonephritis





Interpreting MORL Complement-Mediated Kidney Disease Genetic and Functional Results

GENETIC TESTING		
Gene	**Chromosomal Location**	**Interpretation**
Complement gene that has been reported to be associated with TMAs/C3G	The specific location on a chromosome of a given gene	**Pathogenic known**: a variant that has been proven to be disease-causing **Likely pathogenic**: a variant that is likely to be disease causing based on current data **Unknown significance:** a variant for which further interpretation is not possible based on available data **Likely benign:** a variant not known to cause disease

PATHWAYS			AUTOANTIBODIES					
CH50 (41-95 Units/mL	**APFA** (50-130%)	**C3b Deposition Assay** (normal)	**FH Autoantibody** (<200 AU)	**FB Autoantibody** (<200 AU)	**Fluid Phase Activity -IFE** (<7.5%)	**C3Nef - C3CSA** (<20%)	**C5Nef- C3CSAP** (<20%)	**C4Nef** (<20%)
Determines whether the CP is overactive or whether a CP protein has been abnormally consumed	Determines whether the AP is overactive or whether an AP protein has been abnormally consumed	Identifies whether abnormal C3 activation is occurring	An antibody that binds to Factor H (FH); can interfere with FH function and compromise AP regulation	An antibody that binds to Factor B (FB); can interfere with C3 convertase regulation; often seen in PIGN	Determines if a protein in the blood is causing complement dysregulation/activation	Antibodies to C3- or C5-convertase, preventing them from naturally falling apart		Similar to C3- or C5-nephritic factors, however they stabilize the classical pathway convertase

BIOMARKERS												
	C3 level (90-180 mg/dL)	**C3c Level** (<1.5 mg/L)	**C4 Level** (15-47 mg/dL)	**FB Level** (22-50 mg/dL)	**Ba Level** (<1.2 mg/L)	**Bb Level** (<2.2 mg/L)	**FD Level** (0.78-1.59 mg/L)	**C5 Level** (13.5-27 mg/L)	**Properdin Level** (10-33 mg/L)	**Soluble C5b-9** (<0.3 mg/L)	**FI Level** (18-44 mg/L)	**FH Level** (180-420 mg/L)
High Result	Represents inflammation or obesity. A breakdown product of C3, suggests overactivity of the AP	A breakdown product of C3, suggests overactivity of the AP	Represents inflammation	Represents inflammation	Cleavage products of FB; high levels mean that FB is being consumed excessively; high levels of Ba are also seen with ESKD		High levels of Factor D (FD) suggest declining kidney function irrespective of complement activity	Elevated with terminal complement pathway inhibitor		Increased activity of the terminal complement pathway	Represents inflammation	Represents inflammation
Low Result	Deficient because of a gene abnormality or inappropriately consumed		Deficient because of a gene abnormality or inappropriately consumed	Deficient because of a gene abnormality or consumed due to overactive AP				Suggests terminal pathway hyperactivity	Suggests terminal pathway hyperactivity	Low if on terminal complement blockade	Deficiency typically reflects a gene abnormality	Deficiency typically reflects a gene abnormality or inappropriate consumption

* AP = Alternate Pathway; CP = Classical Pathway; Nef = Nephritic Factor, ESKD= End Stage Kidney Disease; laboratory results may be significantly altered by inappropriate specimen handling; due to the extreme complexity of the complement cascade, assessing complement activity and regulation is best performed by pathway analysis, together with autoantibody testing and biomarker profiling as opposed to doing tests in isolation