Methods to Estimate and Measure Renal Function (Glomerular Filtration Rate)

A Systematic Review

The full report contains tables in English that present included studies

Swedish Council on Health Technology Assessment

SBU Board of Directors and Scientific Advisory Committee

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Summary and Conclusions of the SBU Report:

Methods to Estimate and Measure Renal Function (Glomerular Filtration Rate)

A Systematic Review

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Accurate estimates of kidney function are essential for appropriate treatment decisions. The best measure of kidney function is the glomerular filtration rate (GFR). To measure GFR is complicated in clinical practice, requiring substantial time and resources. Alternatively, GFR can be estimated from a blood sample by using equations (eGFR) based on the plasma concentration of creatinine or cystatin C. Creatinine is formed in muscles as a break-down product of creatine, while cystatin C is a small protein produced by nearly all cells in the body.

Is it uncertain which biomarkers and equations yield the most accurate estimates of GFR, and opinions and practices vary. The cost-effectiveness of various methods has also been questioned. This report aims to review how accurately the different equations based on creatinine, cystatin C, or a combination of both markers, can estimate GFR in different patient groups. We have not evaluated either the direct benefits to patients' health or the levels of accuracy required in different clinical situations.

SBU's Conclusions

❑ Equations based on the plasma concentration of creatinine or cystatin C generally estimate kidney function (GFR) with sufficient and equal accuracy. This option is currently under-utilized in clinical practice.[1] Factors such as muscle mass and meat intake (for creatinine) and corticosteroid medication (for cystatin C) should be considered when evaluating estimated GFR. Equations based on cystatin C alone are generally accurate, while creatinine-based equations, to be equally accurate, must include certain demographic information

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[1] In usual practice, an eGFR equation is defined as having *sufficient* accuracy when at least 75% of the estimates fall within ±30% of the measured GFR.

(eg age and sex) and, at times, anthropometric measurements (weight and height).

❑ The mean value of estimated GFR based on both creatinine and cystatin C is more accurate than equations based on either. This is not widely known. This applies especially to adult patients with low GFR (<30 mL/min/1.73 m²) and children.

❑ Creatinine-based equations are not sufficiently accurate in children with low BMI (<20 kg/m²). In the elderly (>80 years) just a few, eg the revised Lund-Malmo equation (LM-rev), are sufficiently accurate. In these patient groups the accuracy of cystatin C-based equations and equations based on the mean value of creatinine and cystatin C has not been adequately studied.

❑ When impaired kidney function is suspected, using both creatinine and cystatin C in estimating GFR is probably more cost-effective than using only one of the methods.

❑ Laboratories should report estimated GFR, thereby giving the healthcare provider a measure of kidney function instead of reporting just the creatinine value, as done previously. GFR can be estimated with sufficient accuracy from both creatinine and cystatin C, at least up to 90 mL/min/1.73 m².

❑ Swedish laboratories currently use several analytical methods and equations to estimate GFR. Greater uniformity is desirable. Analyses of cystatin C should be traceable to the international cystatin C calibrator. Equations based on IDMS-traceable creatinine analyses[2] (MDRD, CKD-EPI, and LM-rev) should

conclusions

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[2] IDMS = Isotope dilution mass spectrometry, an internationally certified standard for plasma creatinine analysis.

be used. LM-rev is developed in Sweden and is at least as accurate as the above-mentioned equations. The Cockcroft-Gault creatinine-based equation is substantially less accurate and should not be used.

❑ Endogenous creatinine clearance is still used to measure GFR. This method overestimates GFR and should be discontinued.

SBU's Summary

Background and aim

The kidneys have a vital role in controlling and adjusting our internal environment. They regulate acid-base, fluid and salt balance, the excretion of waste products, toxic substances, and drugs. The kidneys also influence red blood cell formation, mineral metabolism, blood pressure and several other endocrine functions. Without kidney function, death occurs in a few days up to a week due to electrolyte imbalance and the accumulation of fluid and waste products.

Glomerular filtration rate (GFR) is measured in mL/min and is usually normalised to a body surface area of 1.73 m². In a healthy young adult, GFR is 100 to 130 mL/min/1.73 m². GFR decreases with increasing age, but opinions differ about when the age-related decline begins. Starting from 40 to 50 years of age, GFR appears to decrease approximately 10 mL/min/1.73 m² per decade.

Besides age, the most common reasons for deteriorating kidney function include general arteriosclerosis, diabetes, and chronic nephritis. Decreased GFR increases the risk of complications, eg in conjunction with surgery, pharmacotherapy, and injection of radiologic contrast media. Impaired kidney function also entails serious risks for development and exacerbation of cardiovascular disease. Severely reduced GFR, <15 mL/min/1.73 m², leads to uraemia, which for survival may require dialysis or kidney trans-

plantation. Other important signs of kidney damage include haematuria and/or albuminuria.

Measuring GFR

GFR cannot be measured directly in the kidneys since filtration occurs in parallel in millions of glomeruli and the primary urine undergoes substantial volume and compositional changes travelling through the kidney. However, GFR can be measured by calculating the rate by which a marker injected into the bloodstream is eliminated in urine. One such marker is inulin, a polysaccharide that is filtered through the renal glomeruli and neither secreted nor reabsorbed in the kidney. These features enable inulin to be used in measuring GFR; renal clearance of inulin is considered to be the gold standard. However, the method is complicated; thus expensive. Other substances that are used to measure GFR include renal or plasma clearances of DTPA (diethylene-triamine penta-acetic acid), ^{51}Cr-EDTA (radioactively tagged ethylenediaminetetra-acetic acid), iohexol (x-ray contrast medium), iothalamate (radioactively tagged contrast medium) plasma clearance of inulin, and endogenous clearance of creatinine (renal clearance of creatinine). We have not found any systematic reviews that demonstrate which of these less complicated methods are sufficiently accurate to use as a gold standard in measuring GFR.

Estimating GFR

For many years methods to estimate GFR have been developed as alternatives to measuring GFR. The most common is based on creatinine; in 2011 over 7 million creatinine analyses were performed in Sweden. The plasma concentration of creatinine increases as GFR decreases; an elevated concentration is thus a rough indicator of impaired kidney function. However, the concentration of creatinine in plasma also depends on muscle mass and several formulas have been developed to estimate GFR from

creatinine while taking into consideration age, sex, and in some cases ethnicity, weight, and height. Which creatinine equation yields the most accurate estimate of GFR in different situations and in different disorders is still an open question.

An alternative marker for estimating kidney function is cystatin C, a low-molecular-weight protein produced in all human cells having a nucleus. Like creatinine, cystatin C is filtered freely through glomeruli. Estimation of GFR from cystatin C does not require information about age, sex, ethnicity, weight or height. Hence, cystatin C is being used increasingly in Sweden and elsewhere. In 2011, approximately 240 000 analyses of cystatin C were performed in Sweden. Whether, and in which situations, cystatin C should be used to estimate kidney function is controversial.

In addition to equations based on either creatinine or cystatin C alone, combined equations exist that are based on both markers. A combined equation may be either a mean value equation, ie the mean of estimations of GFR with either marker, or a composite equation containing both markers.

This report aims to:

1. Establish which methods are sufficiently accurate to be used as reference methods for measuring GFR.

2. Establish the accuracy of measuring kidney function in different patient groups using equations based on the plasma concentration of creatinine and/or cystatin C.

3. Evaluate different alternatives for appraising kidney function from the perspectives of ethics and health economics. The report also investigates current practice regarding selection and extent of kidney function analyses in Sweden.

Questions and limitations

The overriding question is: How well does a GFR estimated by equations based on the plasma concentration of creatinine and cystatin C, respectively, correspond to GFR measured by an accepted reference method?

The specific questions are:

- Which of the methods endogenous creatinine clearance, renal clearance and plasma clearance of ^{51}Cr-EDTA, DTPA, iohexol, and iothalamate, respectively, and plasma clearance of inulin are equally accurate as the renal clearance of inulin measured during continuous infusion for measuring GFR?

- Which creatinine equation yields the most accurate estimate of GFR in large groups of adult and child patients?

- Do cystatin C equations provide more accurate estimates of GFR than equations based on creatinine?

- Do equations combining creatinine and cystatin C provide more accurate estimates than equations based on either marker alone?

- How accurately is GFR estimated in subgroups divided according to kidney function, age, sex, ethnicity, and BMI?

- Do cystatin C equations provide more accurate estimates of GFR than equations based on creatinine in specific patient groups, eg patients with organ transplants, liver cirrhosis or diabetes?

- What are the ethical aspects of estimating kidney function?

- What are the total costs and the cost-effectiveness of creatinine, cystatin C, or a combination of these as markers in estimating kidney function?

- What is current practice in Sweden for measuring and estimating kidney function?

The following were not assessed:

- Evaluation of kidney function based only on the plasma concentration of creatinine and cystatin C, respectively, without equations.

- Which marker, ie creatinine or cystatin C, is superior for monitoring changes in kidney function?

- Which estimate of GFR based on creatinine or cystatin C provides the best prognostic information about future risks of morbidity and mortality?

- Drug dosing, when the dosing instructions are based only on creatinine, endogenous creatinine clearance, or estimated GFR using, eg the Cockcroft-Gault equation. The main reason is that dosing instructions are based on a specific method to estimate GFR. If the method changes, it would become necessary to investigate the effects of this on each such drug separately.

Method

SBU uses a systematic methodology to search all relevant literature in available databases. Each of the included studies has been evaluated for quality and tabulated according to a special method. The review includes an evaluation of the studies' topical relevance and methodological quality – study design, internal validity,

statistical uncertainty, and generalisability. Health economists were involved in reviewing articles addressing health economics. The findings have been graded on the strength of the scientific evidence.

**Measures for determining the capability
of a method to estimate or measure GFR**

The outcome measures used in this report are based on international practice that has developed within the field and that many authors currently use. The two main measures used to evaluate how well the different estimating equations correspond to measured GFR are bias and P30.

Bias indicates the systematic error in estimated GFR and is expressed as the mean or median difference between estimated and measured GFR in either absolute (mL/min or mL/min/1.73 m²) or relative (percentage) values. P30 indicates the proportion of estimated GFR values that fall within ±30% of the measured GFR values and is considered a robust standard. Thus, a P30 of 75% means that 75% of the estimated GFR values fall within ±30% of the measured values. For example: for GFR= 60 mL/min/1.73 m² and a P30 of 75%, 75% of the estimates will fall between 42 and 78 ml/min/1.73 m² (±30% of 60 mL/min/1.73 m²). Occasionally P10 is used to show the percentage of estimated values that fall within ±10% of measured GFR values. The requirements regarding bias and accuracy are higher for gold standards than for equations (Tables 1 and 2).

Facts 1 Study quality, relevance and evidence grading.

Study quality refers to the scientific quality of an individual study and its capacity to answer a specific question in a reliable way.

Evidence grade refers to the appraised strength of the collective body of scientific evidence and its capacity to answer a specific question in a reliable way. SBU uses the international evidence grading system GRADE. Factors that can increase or decrease the strength of the evidence include: study design, study quality, relevance, consistency, transferability, effect size, data precision, risk of publication bias, and other aspects, eg the dose-response relationship.

Evidence grades – four levels

Strong scientific evidence (⊕⊕⊕⊕)
Based on high or moderate quality studies with no factors that weaken the overall assessment.

Moderately strong scientific evidence (⊕⊕⊕◯)
Based on high or moderate quality studies with isolated factors that weaken the overall assessment.

Limited scientific evidence (⊕⊕◯◯)
Based on high or moderate quality studies having factors that weaken the overall assessment.

Insufficient scientific evidence (⊕◯◯◯)
Scientific evidence is considered insufficient when scientific findings are absent, the quality of available studies is low, or studies of similar quality present conflicting findings.

The stronger the evidence, the lower the likelihood that new research findings would affect the documented results within the foreseeable future.

Conclusions
SBU's conclusions present an overall assessment of benefits, risks, and cost effectiveness.

Evidence-graded results

Methods for measuring GFR

Table 1 summarises the accuracy of methods for measuring GFR. Renal clearance of ^{51}Cr-EDTA, iothalamate, DTPA, and iohexol and plasma clearance of ^{51}Cr-EDTA, iohexol, and inulin are methods with sufficient accuracy to be used as gold standards. The evidence is strongest for the renal clearance of iothalamate. Strong scientific evidence indicates that endogenous creatinine clearance (renal) is insufficiently accurate for use as a gold standard. Likewise, plasma clearance of DTPA and iothalamate are insufficiently accurate, but this conclusion is based on limited or insufficient scientific evidence.

Table 1 *Summary of the most important findings and strength of the evidence regarding the accuracy of different index methods for measuring kidney function (GFR) compared to renal clearance of inulin.*

Index method	Sufficient accuracy[*]	Strength of the evidence
Iothalamate renal clearance	Yes	⊕⊕⊕⊕
[51]Cr-EDTA renal clearance ^{51}Cr-EDTA plasma clearance Iohexol plasma clearance	Yes	⊕⊕⊕○
DTPA renal clearance Iohexol renal clearance Inulin plasma clearance	Yes	⊕⊕○○
Endogenous creatinine clearance	No	⊕⊕⊕⊕
DTPA plasma clearance	No	⊕⊕○○
Iothalamate plasma clearance	Information not available	⊕○○○

[*] Requirements for sufficient accuracy: P10 ≥50%, P30 ≥80% (the percentage of results measured with the index method that fall within 10% and 30%, respectively, of corresponding renal clearance of inulin) and the percentage of bias ≤±5% (the median error between the index method and renal clearance of inulin).

Equations for estimating GFR

Table 2 summarises the accuracy of the four best documented creatinine equations, cystatin C equations, and equations combining both markers.

The mean value of estimated GFR based on creatinine and cystatin C generally yields higher accuracy than equations based on only one of the markers. The improvement is most evident in children and in patients with low GFR (<30 mL/min/1.73 m²). Evidence is lacking for corresponding comparisons at different BMI intervals and in individuals over 80 years of age.

Generally, the creatinine-based equations from the Modification of Diet in Renal Disease Study (MDRD), the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI), and the revised Lund-Malmö equation (LM-rev) are all in general sufficiently accurate (P30 ≥75%) for estimating kidney function in adults, except in patients with GFR <30 mL/min/1.73 m² or BMI <20 kg/m². The accuracy of the Cockcroft-Gault (CG) creatinine equation is insufficient (P30 <75%), particularly at GFR <60 mL/min/1.73 m².

In individuals above 80 years of age, the creatinine-based equations (CKD-EPI and LM-rev) are sufficiently accurate. In children, all creatinine-based equations have insufficient accuracy.

Cystatin C equations, in general, yield sufficient accuracy in adults and are equivalent to the best creatinine equations. Accuracy is also sufficient in children, but the evidence is limited. Evidence is not available for assessing the accuracy of cystatin C equations at different BMI intervals and in individuals above 80 years of age.

Table 2 *Summary of the most important findings and the strength of the evidence regarding accuracy in estimating GFR (mL/min/ 1.73 m^2) with creatinine, cystatin C, and combined equations in large patient groups. P30 = Percentage of estimated GFR within*

	Creatinine equations	
	Cockcroft-Gault (CG)	**MDRD**
Adults		
Principal results	No ↑ ⊕⊕⊕⊕	Yes ⊕⊕⊕⊕
GFR interval (mL/min/1.73 m^2)		
<30	No ↑ ⊕⊕⊕○	No ⊕⊕⊕○
30–59	No ↑ ⊕⊕⊕○	Yes ⊕⊕⊕○
60–89	Yes ⊕⊕⊕○	Yes ⊕⊕⊕○
≥90	Yes ⊕⊕⊕○	Yes ↓ ⊕⊕⊕○
Age interval (year)		
<40	– ⊕○○○	Yes ⊕⊕⊕○
40–79	– ⊕○○○	Yes ⊕⊕⊕○
≥80	– ⊕○○○	No ↑ ⊕⊕○○
BMI interval (kg/m^2)		
<20	– ⊕○○○	No ↑ ⊕⊕○○
20–39	– ⊕○○○	Yes ⊕⊕○○
≥40	– ⊕○○○	– ⊕○○○
Specific ethnic groups in Sweden	– ⊕○○○	– ⊕○○○
Children		
	CG, MDRD, EKD-EPI	**Schwartz original**
Principal results	Not applicable in children	No ⊕⊕⊕⊕
Sex, GFR age and BMI intervals	Not applicable in children	– ⊕○○○

* Schwartz-IDMS showed equivalent and sufficient accuracy compared to cystatin C equations in pairwise comparisons. However, on the whole, Schwartz-IDMS was insufficiently accurate when studies that did not show comparisons with cystatin C were also included.

±30% of measured GFR. Yes = Sufficient accuracy: P30 ≥75%. No = Insufficient accuracy: P30 <75%. Bias is not part of the requirements for accuracy, but the arrows in the table indicate bias >10% (↑ = Overestimation, ↓ = Underestimation).

Creatinine equations		Cystatin C equations	Combination equations
CKD-EPI	**LM-revised**		
Yes ⊕⊕⊕⊕	Yes ⊕⊕○○	Yes ⊕⊕⊕○	Yes ⊕⊕⊕○
No ⊕⊕⊕○	No ⊕⊕○○	No ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕⊕○	Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕⊕○	Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕⊕○	Yes ↓ ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
Yes ⊕⊕○○	Yes ⊕⊕○○	– ⊕○○○	– ⊕○○○
No ↑ ⊕⊕○○	No ↑ ⊕⊕○○	– ⊕○○○	– ⊕○○○
Yes ⊕⊕○○	Yes ⊕⊕○○	– ⊕○○○	– ⊕○○○
– ⊕○○○	– ⊕○○○	– ⊕○○○	– ⊕○○○
– ⊕○○○	– ⊕○○○	– ⊕○○○	– ⊕○○○

Schwartz IDMS	LM original LM-rev	Cystatin C equations	Combination equations
No* ⊕⊕⊕○	No ⊕⊕○○	Yes ⊕⊕○○	Yes ⊕⊕○○
– ⊕○○○	– ⊕○○○	– ⊕○○○	– ⊕○○○

– = Information not available.

Comparing accuracy of equations based on creatinine and cystatin C in specific patient groups

In summary, the evidence is insufficient to assess whether the accuracy of estimating GFR differs between creatinine- and cystatin C-based equations in patients with specific conditions, eg organ transplants and diabetes (insufficient scientific evidence ⊕◯◯◯).

Accuracy in estimating GFR is somewhat lower (P30 <75%) in patients after kidney transplantation compared to pre-transplantation. The same applies to patients with diabetes in comparison to patients without diabetes, regardless of whether creatinine- or cystatin C-based equations are used. In patients with kidney transplants cystatin C equations tend to underestimate GFR.

In a few studies of large patient groups, where results have been reported separately for patients with organ transplantation or diabetes, the creatinine-based equations are less accurate than in patients without organ transplantation and diabetes. Nevertheless, accuracy is in general, sufficient (P30 approaching or >75%).

Health economics analysis

A health economics analysis shows that estimated GFR based on mean-value equations of creatinine and cystatin C are cost-effective compared to using only one of the markers. The calculations address patients with suspected impairment of kidney function. The results are based on an economic evaluation.

Summary discussion

Important findings and clinical consequences

Generally, kidney function can be estimated with sufficient accuracy using either creatinine- or cystatin C-based equations. The most accurate estimates are achieved using equations that

combine these two markers. If creatinine is used age and gender data must be included in the equation, whereas this information is not required for cystatin C-based equations.

Requirements for accuracy in determining kidney function vary between different patient situations. When a measurement of GFR is warranted (eg nephrological work-up and in making critical clinical treatment decisions eg on drug dosage), plasma clearance of ^{51}Cr-EDTA or iohexol can be utilised. Both these methods are currently used in Sweden and have good, and equivalent, accuracy. Endogenous creatinine clearance, however, overestimates GFR and is not a reliable method.

Analytical methods and reporting by laboratories
Swedish laboratories currently use different analytical methods and equations to estimate GFR. Greater uniformity is desirable. It is important that the methods used nationally to measure marker concentration in plasma are based on uniform calibrations, traceable to the international reference materials now available for both creatinine and cystatin C. Analyses of creatinine should be performed using enzymatic methods to minimise the influence of interfering substances. Equations based on IDMS-traceable creatinine analyses (MDRD, CKD-EPI, and LM-rev) should be used. LM-rev has been developed in Sweden, and is at least as accurate as the aforementioned equations. The Cockcroft-Gault creatinine-based equation is substantially less accurate and should be discarded.

Laboratories report on cystatin C in terms of both plasma concentration (mg/L) and estimated GFR (mL/min/1.73 m²), while creatinine is often reported as plasma concentration (μmol/L). An important conclusion presented in the report is that estimated GFR can be reported also when creatinine-based equations are used, at least up to an estimated GFR of 90 mL/min/1.73 m².

The healthcare provider thus receives a direct estimate of the kidney function of his patient.

Evaluating the laboratory report

When evaluating an estimated GFR, consideration must be given to factors unrelated to GFR that can influence the individual markers. Estimates based on creatinine can be misleading in patients with unusually large or small muscle mass. The same applies to cystatin C in patients taking large doses of glucocorticoids. Both markers yield less accurate estimates during eg pregnancy and in impaired thyroid function.

Not infrequently, non-GFR factors shift estimates based on creatinine and cystatin C in different directions. Access to both allows the doctor to decide which estimate is the most accurate in a particular situation. When in doubt the mean value, which is generally more accurate than either estimate can be used. The improved accuracy probably results from the markers compensating for each other's shortcomings.

Ethical aspects

Routine reporting of estimated GFR offers substantial advantages to both patients and care providers. However, guidelines need to indicate when referral to a specialist is required in order not to overutilize health care resources. Guidelines are available in eg Region Skåne (see website links for the Swedish report, www.sbu.se/214).

Health economic aspects

The health economic analysis is based on calculations by the project group. The direct costs for analyses vary by laboratory and client volume. In 2012, costs were 10–15 Swedish kronor (SEK) for creatinine, and SEK 25–50 for cystatin C. The calculations show that if both markers are used when impaired kidney function is

suspected, the more accurate estimate reduces the costs of care; the higher analytical cost in this context is negligible. A more accurate estimate should also lead to more appropriate management and less suffering for the patient.

Limitations of the report

A weakness in the evidence is that most of the included studies are retrospective, based on data already collected from care situations where GFR has been both estimated and measured. Such studies underrepresent patient groups and clinical situations where GFR is seldom, if ever, measured, and this can affect the validity and generalisability of the results.

Reference measurement procedures and materials have been available since the early 2000s for creatinine, but for cystatin C only since 2010. Earlier cystatin C studies have utilized different analytical methods and equations that are more or less laboratory-specific. Although in theory GFR equations based on cystatin C should be superior to those based on creatinine, scientific evidence is lacking. Table 2 shows several areas where evidence is insufficient or lacking for evaluating the accuracy of cystatin C-based equations. A yet unpublished Swedish study, which used the international calibrator, shows that the best cystatin C equations (in contrast to the creatinine equations) provide sufficient accuracy even at GFR <30 mL/min/1.73 m² and at low BMI (<20 kg/m²). This could change the conclusions regarding these patient groups in the future.

Drug dosing

In dosing drugs, including radiological contrast agents, GFR estimating equations usually suffice. Occasionally a measured GFR is required, eg for certain cancer drugs where precise dose adjustment is critical. For many drugs (primarily older drugs), dosing is based on the Cockcroft-Gault equation or endogenous creatinine

clearance, methods of insufficient accuracy. It is uncertain how these dosing instructions can be adapted to more accurate methods to estimate kidney function. The problem has received international attention and the US Food and Drug Administration (FDA) is currently discussing which creatinine-based equation should be used for dosing of drugs whose elimination depends on kidney function. The aim should be to base drug dosing and dosing instructions on the most accurate methods for estimating kidney function.

Uncertainties

The performance of creatinine and cystatin C GFR estimating equations in certain patients groups needs further investigation. This applies to children, especially children with impaired kidney function where accuracy data with regard to sex, age, and BMI intervals are lacking, and in adults with BMI <20 kg/m².

For patients over 80 years of age, the scientific evidence is limited as to whether the two creatinine-based equations (CKD-EPI and LM-rev) yield sufficient accuracy, and evidence is lacking to evaluate the accuracy of cystatin C equations. Elderly, multi-morbidity patients comprise a particularly important group for study, since not infrequently they may take many different drugs and live in special housing where the opportunities for measuring GFR are limited.

The scientific evidence is often insufficient to determine which methods provide the best estimation of GFR in specific patient groups. Methods for estimating GFR during pregnancy need to be developed, as do methods for estimating GFR in children. We found no studies on infants under 1 year of age. Patients in intensive care constitute another important group, particularly those with lengthy care episodes and complicated disorders. A signi-

ficant loss of muscle mass in these patients can lead to reduced plasma concentrations of creatinine and inaccurately high eGFR values.

Knowledge is needed concerning the benefits and costs of the different alternatives (ie equations using creatinine or cystatin C alone, or combined equations) for estimating kidney function in different patient groups.

Using the international calibrator for cystatin C, future studies can increase our knowledge about the accuracy of estimating GFR from cystatin C in different situations and for different conditions. Similarly, there is a need for studies comparing GFR estimates from creatinine and cystatin C where concentration measurements of both markers are traceable to high-order reference measurement procedures. To a greater extent, the accuracy of the equations should be compared prospectively, including patients groups and clinical situations where gold standards are not normally used to measure GFR.

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All SBU reports are published in Swedish. The summaries and some reports are also published in English. Summaries and reports can be downloaded at www.sbu.se, or ordered by email (sbu@strd.se), by phone (+46-8-779 96 85) or by fax (+46-8-779 996 10).

SBU Evaluates
Health Care Technology

Below is a brief summary of the mission assigned to SBU
by the Swedish Government:

- SBU shall assess healthcare methods by systematically and
  critically reviewing the underlying scientific evidence.

- SBU shall assess new methods as well as those that are already
  part of established clinical practice.

- SBU's assessments shall include medical, ethical, social and
  economic aspects, as well as a description of the potential
  impact of disseminating the assessed health technologies
  in clinical practice.

- SBU shall compile, present and disseminate its assessment
  results such that all parties concerned have the opportunity
  to take part of them.

- SBU shall conduct informational and educational efforts to
  promote the application of its assessments to the rational use
  of available resources in clinical practice, including dental care.

- SBU shall contribute to the development of international co-
  operation in the field of health technology assessment and serve
  as a national knowledge centre for the assessment of health
  technologies.

Methods to Estimate and Measure Renal Function (Glomerular Filtration Rate)

The report on methods to estimate and measure renal function (glomerular filtration rate) from the Swedish Council on Health Technology Assessment (SBU) is a systematic review of the scientific literature in the field.

This document presents the summary and conclusions of the full report approved by SBU's Board and Scientific Advisory Committee.

The full report is available at www.sbu.se