

Simple Measurement of Intra-abdominal Fat for Abdominal Surgery Outcome Prediction

Katherine Morris, MD; Scott Tuorto, BA; Mithat Gönen, PhD; Lawrence Schwartz, MD; Ronald DeMatteo, MD; Michael D'Angelica, MD; William R. Jarnagin, MD; Yuman Fong, MD

Objective: To assess the effect of increasing body mass index, intra-abdominal fat, and outer abdominal fat on outcome in patients undergoing major hepatectomy.

Design: Cohort study.

Setting: Memorial Sloan-Kettering Cancer Center.

Participants: We studied patients aged 19 to 86 years undergoing major hepatic resection between June 18, 1996, and November 6, 2001. Complications were extracted from a prospective database at a tertiary cancer center.

Intervention: A total of 349 patients were grouped according to body mass index for analysis. Preoperative abdominal computed tomographic scans were examined and measurements of perinephric fat (as a surrogate for intra-abdominal fat) and outer abdominal fat taken at uniform anatomical locations.

Main Outcome Measures: We compared 30-day mortality and morbidity figures, length of stay, and operating times.

Results: Body mass index had an influence on operative time ($P=.02$) but no significant effect on mortality, frequency of any complications, frequency of severe complications, or length of stay ($P=.80$, $P=.89$, $P=.16$, and $P=.81$, respectively). Outer abdominal fat had no significant effect on any of the 5 outcome measures. Perinephric fat measurements had a significant effect on most outcome measures ($P=.004$ for mortality, $P=.003$ for frequency of complications, $P<.001$ for frequency of severe complications, and $P=.001$ for length of stay).

Conclusions: Outer appearances of obesity do not correlate with poor outcomes for major upper abdominal operations. A simple measurement of perinephric fat, as a surrogate for intra-abdominal fat, on preoperative imaging gives a more useful risk assessment for patients undergoing major upper abdominal operations.

Arch Surg. 2010;145(11):1069-1073

DATA FROM THE 2008 NATIONAL Health and Nutrition Examination Survey¹ reveal that 65% of the US population is currently overweight, defined as having a body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) of 25 to 29.9. Nearly half these people, having a BMI of 30 or higher, are included in the definition of obese. There has been a 30% increase in the incidence of obesity from 1978 to 1999.¹ This increase requires surgeons to examine more critically the effect of overweight and obesity on their patients. The literature²⁻¹³ currently presents mixed findings on the effect of overweight and obesity on various surgical populations, with different measures of obesity being used in these studies. The goal of this study was to assess the effect of key measures of obesity on a group of patients undergoing major hepatic resection. We postulated that the amount of intra-abdominal fat (IAF) would have the greatest effect on outcome after intra-

abdominal operations. We further postulated that a simple measurement of perinephric fat, easily obtainable on routine computed tomography performed for cancer staging, can be used to stratify patients according to perioperative risk.

See Invited Critique at end of article

METHODS

STUDY DESIGN

At the Memorial Sloan-Kettering Cancer Center, we compared BMI and measurements of IAF and outer abdominal fat (OAF) for their value in predicting rates of death and complications among patients undergoing major upper abdominal surgery. Institutional review board approval was obtained before beginning the study.

STUDY PARTICIPANTS

A consecutive series of all patients undergoing major hepatic resection (defined as ana-

Author Affiliations: Departments of Surgery (Drs Morris, DeMatteo, D'Angelica, Jarnagin, and Fong and Mr Tuorto), Epidemiology and Statistics (Dr Gönen), and Radiology (Dr Schwartz), Memorial Sloan-Kettering Cancer Center, New York, New York.

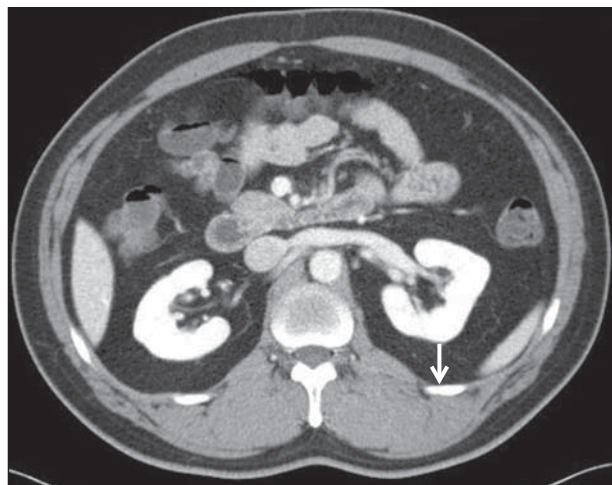


Figure 1. Measurement of intra-abdominal fat (IAF). Computed tomography scans at the level of the renal veins were assessed. The greatest distance between the kidney and the abdominal wall was measured as the IAF (arrow).

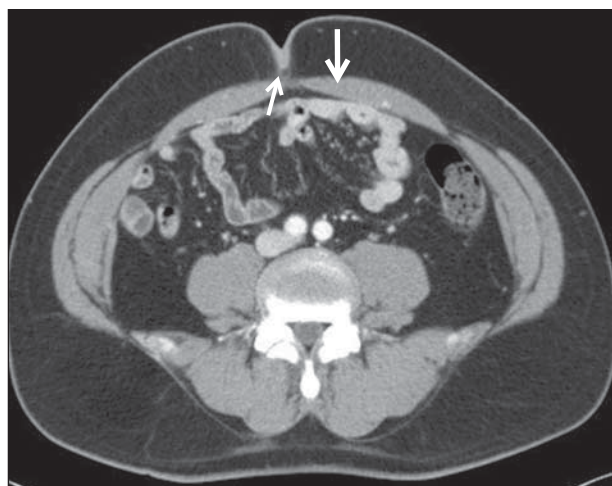


Figure 2. Measurement of outer abdominal fat (OAF). Computed tomography scans were assessed at the level of the umbilicus (short arrow). The thickest anterior abdominal wall distance was measured as the OAF (long arrow).

Table 1. Definition of Grades of Complications

Grade	Complications
0	No event observed beyond 30 days postoperatively
1	Use of oral medications or bedside interventions to treat an event
2	Use of intravenous medications, total parenteral nutrition, enteral nutrition, or blood transfusion to treat an event
3	Interventional radiology, therapeutic endoscopy, intubation, angiography, use of visiting nurse support after discharge, or operation required to treat an event
4	Residual and lasting disability requiring major rehabilitation or organ resection
5	Event resulting in death of patient

tomical resection of at least 1 complete hepatic lobe) between June 18, 1996, and November 6, 2001, comprised this study. Patients younger than 18 years or those whose resection was not completed were excluded. All other eligible patients were included.

INTERVENTIONS

Measurements of BMI were taken from the preanesthesia worksheet for each patient's resection. To obtain objective measures of fat by scanning, standardized computed tomography assessment was used. A single observer (S.T.), masked to the outcomes for the series of patients, examined preoperative computed tomography scans for this cohort. Defined anatomical locations were identified (**Figure 1** and **Figure 2**) and measurements of perinephric fat (IAF) and OAF were made in millimeters on a computer PACS radiology system (GE Pathspeed on 8.1 platform; GE Medical Systems, Fairfield, Connecticut). Thirty-day complications data were obtained from the prospectively maintained surgical complications database at Memorial Sloan-Kettering Cancer Center and confirmed by a detailed review of patient medical records.

DEPENDENT MEASURES

Mortality was defined as death within the 30-day period after surgery. Complications were assessed as binary (present or absent) and ordinal (by grade classification; see **Table 1** for grade definitions) variables. Length of stay was measured in total days in the hospital from admission for operation to discharge. A hospital readmission was defined as a complication and graded based on the cause. Operating time (in minutes) was taken from the nursing records and defined as the time of incision to the time of closure. This was also verified by examination of the anesthesia record.

STATISTICAL ANALYSIS

The 3 measures of obesity considered in this study, BMI, IAF, and OAF, were used as continuous variables. Among the outcomes, operating time and length of stay were evaluated as continuous variables, whereas morbidity was analyzed as binary (yes/no) and ordinal (grades 1-5) measures. Mortality was analyzed as a binary factor. To accommodate the continuous nature of the obesity measures, regression models were used to assess the risk of outcome: logistic regression for mortality and morbidity, proportional odds regression for severity of complications, Poisson regression for length of stay, and least squares regression for logarithm of operation time.

RESULTS

STUDY PARTICIPANTS

Characteristics of the 349 patients, indications for operation, and procedure performed are given in **Table 2**. A summary of outcome measures overall and by sex is given in **Table 3**. Data regarding the 5 outcome measures were analyzed against the BMI, IAF, and OAF for the group as a whole and by sex when important differences between the sexes emerged. In addition, BMI, IAF, and OAF were examined for correlation with each other. Weak to no correlations were observed (**Figure 3**) (correlation coefficients: 0.33 for BMI vs IAF, 0.45 for BMI vs OAF, and -0.02 for IAF vs OAF). A summary of the analysis of the effects of BMI, IAF, and OAF is given in **Table 4**.

The only significant predictor of mortality, frequency and severity of complications, and length of stay was IAF. Multivariate analysis revealed IAF and age to be the only significant predictors of increased risk of mortality. For

Table 2. Summary of Patients, Diagnoses, and Operations Performed

Characteristic	Total (N=349)	Male (n=185)	Female (n=164)	P Value
Age, mean (range), y	59.6 (19.3-86.5)	60.4 (19.3-86.5)	58.7 (29.2-84.4)	.33
BMI, mean (range)	26.8 (15.3-50.3)	27.0 (16.4-42.3)	26.6 (15.3-50.3)	.49
IAF, mean (range), mm	17.7 (2.4-62.8)	21.9 (2.7-62.8)	12.9 (2.4-37.4)	<.001
OAF, mean (range), mm	61.9 (9.3-154.9)	51.8 (9.3-154.9)	73.2 (2.6-149.6)	<.001
Indication for resection, No.				
Metastasectomy	296	164	132	...
Primary liver tumor	39	19	20	...
Benign disease	14	2	12	...
Resection type, No.				
Right hepatectomy	195	100	95	...
Right trisectorectomy	101	59	42	...
Left hepatectomy	52	25	27	...
Left trisectorectomy	1	1	0	...

Abbreviations: BMI, body mass index; ellipses, not applicable; IAF, intra-abdominal fat; OAF, outer abdominal fat.

Table 3. Summary of Outcomes

Outcome Measure	No. (%) of Patients ^a			P Value
	Total (N=349)	Male (n=185)	Female (n=164)	
Mortality	9 (2.6)	6 (3.2)	3 (1.8)	.51
Complication rate	230 (65.9)	135 (73.0)	95 (57.9)	.003
Complication grade, mean when present	2.62	2.67	2.60	.37
Complication grade				
0	119 (34.1)	50 (27.0)	69 (42.1)	.003
1	39 (11.2)	23 (12.4)	16 (9.7)	
2	27 (7.7)	11 (5.9)	16 (9.7)	
3	155 (44.4)	95 (51.4)	60 (36.6)	
4	0	0	0	
5	9 (2.6)	6 (3.2)	3 (1.8)	
Length of stay, mean (range), d	10.8 (2.0-67.0)	11.7 (5.0-67.0)	9.7 (2.0-27.0)	.006
Operating time, mean (range), min	275.6 (100.0-680.0)	283.2 (100.0-680.0)	267.0 (115.0-540.0)	.10

^aData are number (percentage) of patients unless otherwise indicated.

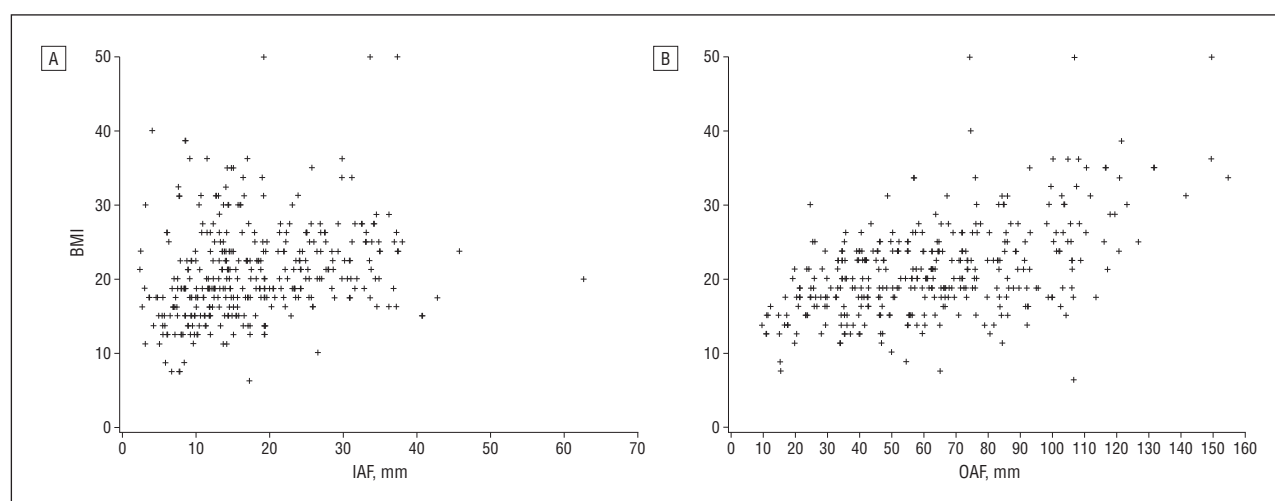


Figure 3. Correlation of fat to body mass index (BMI, calculated as weight in kilograms divided by height in meters squared). A, Intra-abdominal fat (IAF); B, outer abdominal fat (OAF). The correlation coefficients were 0.33 for IAF and 0.47 for OAF.

the other variables, differences in the models emerged between the sexes, so the analyses were performed for each sex. For men, IAF again emerged as a significant predictor of increasing frequency of complications ($P=.04$) and

increasing length of stay ($P=.002$). Age was not predictive of poor outcomes for men. For women, IAF was not a significant predictor of increased rate of complications ($P=.51$) in multivariate modeling, but age was ($P=.01$).

Similar conclusions emerged when only severe complications (grade >2) were considered.

Analysis of outcome measures was also performed for the subset of patients with a BMI of 30 or higher (82 [23.5%]) to see whether the very obese population had significantly more complications. No difference was found between the 2 groups, and the results of these analyses held true in the subset of obese patients.

COMMENT

The literature regarding the effect of obesity on outcomes for operations has been mixed. Although much of the cardiac surgery literature documents no increase in adverse outcomes for the obese,²⁻⁷ data regarding outcomes in pelvic procedures demonstrate an increase in certain complications, such as increased blood loss and wound infections.⁸ The potential effect of surgical site on effect of obesity is also seen in an article examining the effect of a BMI higher than 27 on colorectal resection. Benoist and colleagues⁹ found no difference in overall mortality, morbidity, or leakage rates for patients undergoing right-sided colectomies but noted increased intra-abdominal fluid collections, anastomotic leak rates, and transfusion rates in patients undergoing left-sided colectomies or proctectomies. We hypothesized that not just obesity but also location of fat influenced outcome of surgery at that site. Using perirenal fat as a surrogate of IAF, the current study confirmed the importance of local fat on outcome of a major upper abdominal operation.

There have been limited studies of the effect of general obesity on outcomes for upper abdominal operations. Outcomes after distal gastrectomy and D2 lymphadenectomy between patients with a BMI lower than 27 and 27 or higher were examined by Japanese investigators,¹⁰ who found a significant increase in intra-abdominal infection rates (7 of 390 [1.8%] in patients with a BMI <25 for men and <22 for women vs 4 of 40 [10.0%] for patients with a BMI >27). In addition, this study found an increase in the length of stay for patients in the group with BMI of 27 or higher (26 vs 34 days). It is not clear how to apply this study to US populations, however, given the different practice patterns and lower frequency of obesity in the Japanese and world populations (7.2% had a BMI >27 in this study).¹⁰ This lower level of obesity in the Japanese patient explains the lower cutoff for obesity in other studies from this country. Thus, in another report from Japan,¹¹ a BMI of 25 was chosen as the cutoff. At this level, no difference in morbidity or length of stay was seen in patients classified as obese (BMI ≥25) vs normal weight (BMI <25) who underwent laparoscopic-assisted distal gastrectomy. A French study¹² found a difference in the incidence of intra-abdominal complications after distal pancreatectomy for patients with a BMI of 27 or higher, but only 12 of 61 (19.7%) patients met this criterion. In the United States, a BMI of 30.0 or higher is usually considered obese. These studies were also confounded by combined analysis of men and women. In the current study, different results were found according to sex and likely reflect the different distribution of body fat by sex. We therefore believe that local assessment of

Table 4. Differences in Outcomes by BMI, IAF, and OAF^a

Outcome Measure	OR (95% CI)	P Value
Mortality		
BMI	1.02 (0.88-1.18)	.80
IAF	1.09 (1.03-1.16)	.004
OAF	0.99 (0.97-1.01)	.39
Frequency of complications		
BMI	1.00 (0.96-1.05)	.89
IAF	1.04 (1.01-1.07)	.003
OAF	0.99 (0.98-1.01)	.11
Frequency of severe complications (grade 3 and higher)		
BMI	1.031 (0.988-1.075)	.16
IAF	1.046 (1.021-1.071)	<.001
OAF	0.994 (0.986-1.001)	.11
Length of stay ^b		
BMI	0.002 (-0.010-0.014)	.81
IAF	0.012 (0.005-0.019)	.001
OAF	-0.002 (-0.001-0.004)	.21
Operating time ^{b,c}		
BMI	0.011 (0.002-0.020)	.02
IAF	0 (-0.001-0.001)	.77
OAF	0 (-0.001-0.001)	.85

Abbreviations: BMI, body mass index; CI, confidence interval; IAF, intra-abdominal fat; OAF, outer abdominal fat; OR, odds ratio.

^aPerinephric fat used as a surrogate measurement.

^bData for length of stay and operating time are slope (95% CI).

^cData were log transformed before analysis because of skewed data.

fat is a better discriminator of risk compared with general obesity.

Other groups have tried to use detailed measurements of IAF to assess risk. A study¹³ reporting on outcomes based on a computer-summed model of levels of IAF dichotomized the continuous variable of IAF and found an increased level to be associated with increased risk of medical, but not surgical, complications. In the current study, we attempted to simplify the measure of IAF for preoperative risk stratification. By using a simple linear measurement of perinephric fat, we found a correlation to increased risk of complications for liver resection.

Looking at a consecutive series of similar major upper abdominal operations allows us a better picture of the rate of complications and possible links of morbidity and mortality to obesity. Interestingly, we did not find the association of increasing morbidity with increasing BMI despite a mean BMI of 26.8 (well into the overweight category) and a full 23.5% of our patients meeting criteria for obesity with a BMI of 30 or higher. As defined by a simple, single surrogate measurement of perinephric fat, IAF was able to be used to risk stratify the patients for mortality, complication rate, severity of complications, and increasing length of stay. This should help surgeons be better able to identify high-risk patients and, conversely, not refuse an operation based on the presumed high risk of someone with external obesity. Now that most of our patients being considered for a major upper abdominal resection will have a preoperative computed tomography scan, the information provided by looking at levels of perinephric fat is easily determined and should not be ignored.

Body mass index seems to be a poor index of the type of obesity that increases operative risk for patients under-

going major hepatic resection. Only a limited number of our patients fell into the morbidly obese (BMI ≥ 40.0 –49.9; $n=2$) and superobese (BMI >50.0 ; $n=1$) categories. Therefore, these data would not be applicable to those particular groups. Evaluating a population of primarily oncology patients may be one reason BMI did not work as an indicator because many of these patients have often undergone weight shifts with ongoing treatment of their malignant neoplasms. Most of our patients had undergone surgery for metastatic disease and had been exposed to varying regimens of chemotherapy, posing unknown effects on nutritional status and body composition that would not have been seen in a population with benign disease.

In this era of increased scrutiny of resource allocation and management, correlation of body measurements to length of hospital stay or operating room time for specific operations may assist in such resource management. Studies such as ours may allow researchers to arrive at a panel of measurements that could be applied in daily planning in hospitals. One could imagine a patient body assessment that can be used to determine reasonable ranges of operating room use, hospital bed occupation, and expected charges for operations. For now, based on these results, we recommend surgeons use IAF and perinephric fat as a guide to judging risk for their patients undergoing major upper abdominal operations.

Accepted for Publication: September 6, 2009.

Correspondence: Yuman Fong, MD, Department of Surgery, Memorial Sloan-Kettering Cancer Center, 1275 York Ave, New York, NY 10065 (fongy@mskcc.org).

Author Contributions: *Study concept and design:* Morris, Tuorto, Gönen, Schwartz, and Fong. *Acquisition of data:* Tuorto and Schwartz. *Analysis and interpretation of data:* Morris, Tuorto, Gönen, Schwartz, DeMatteo, D'Angelica, and Jarnagin. *Drafting of the manuscript:* Morris, Tuorto, Gönen, and Fong. *Critical revision of the manuscript for important intellectual content:* Morris, Tuorto, Gönen, Schwartz, DeMatteo, D'Angelica, and Jarnagin. *Statistical analysis:* Morris and Gönen. *Administrative, techni-*

cal, and material support: Morris, Tuorto, and Schwartz.

Study supervision: D'Angelica, Jarnagin, and Fong.

Financial Disclosure: None reported.

Funding/Support: This study was supported in part by grant 032047 from Flight Attendant Medical Research Institute.

REFERENCES

1. Prevalence of overweight, obesity, and extreme obesity observed among adults: United States trends 1976-1980 through 2007-2008. Centers for Disease Control and Prevention Web site. http://www.cdc.gov/nchs/data/hestat/obesity_adult_07_08/obesity_adult_07_08.htm. Accessed August 25, 2010.
2. Gruberg L, Mercado N, Milo S, et al: Arterial Revascularization Therapies Study Investigators. Impact of body mass index on the outcome of patients with multivessel disease randomized to either coronary artery bypass grafting or stenting in the ARTS trial: the obesity paradox II? *Am J Cardiol*. 2005;95(4):439-444.
3. Gruberg L, Weissman NJ, Waksman R, et al: The impact of obesity on the short-term and long-term outcomes after percutaneous coronary intervention: the obesity paradox? *J Am Coll Cardiol*. 2002;39(4):578-584.
4. Maurer MS, Luchsinger JA, Wellner R, Kukuy E, Edwards NM: The effect of body mass index on complications from cardiac surgery in the oldest old. *J Am Geriatr Soc*. 2002;50(6):988-994.
5. Minutello RM, Chou ET, Hong MK, et al: Impact of body mass index on in-hospital outcomes following percutaneous coronary intervention (report from the New York State Angioplasty Registry). *Am J Cardiol*. 2004;93(10):1229-1232.
6. Prabhakar G, Haan CK, Peterson ED, Coombs LP, Cruzzavala JL, Murray GF: The risks of moderate and extreme obesity for coronary artery bypass grafting outcomes: a study from the Society of Thoracic Surgeons' database. *Ann Thorac Surg*. 2002;74(4):1125-1131.
7. Vassiliades TA Jr, Nielsen JL, Lonquist JL: Effects of obesity on outcomes in endoscopically assisted coronary artery bypass operations. *Heart Surg Forum*. 2003;6(2):99-101.
8. Lee CT, Dunn RL, Chen BT, Joshi DP, Sheffield J, Montie JE: Impact of body mass index on radical cystectomy. *J Urol*. 2004;172(4, pt 1):1281-1285.
9. Benoist S, Panis Y, Alves A, Valleur P: Impact of obesity on surgical outcomes after colorectal resection. *Am J Surg*. 2000;179(4):275-281.
10. Kodera Y, Ito S, Yamamura Y, et al: Obesity and outcome of distal gastrectomy with D2 lymphadenectomy for carcinoma. *Hepatogastroenterology*. 2004;51(58):1225-1228.
11. Yasuda K, Inomata M, Shiraishi N, Izumi K, Ishikawa K, Kitano S: Laparoscopy-assisted distal gastrectomy for early gastric cancer in obese and nonobese patients. *Surg Endosc*. 2004;18(8):1253-1256.
12. Sledzianowski JF, Duffas JP, Muscari F, Suc B, Fourtanier F: Risk factors for mortality and intra-abdominal morbidity after distal pancreatectomy. *Surgery*. 2005;137(2):180-185.
13. Tsukada K, Miyazaki T, Kato H, et al: Body fat accumulation and postoperative complications after abdominal surgery. *Am Surg*. 2004;70(4):347-351.

INVITED CRITIQUE

Is a "Simple Measurement" of Intra-abdominal Fat a Simple Tool for a Surgeon?

Because surgical decision making is key to surgical outcome, surgeons are constantly searching for simple, reliable methods of risk assessment. Morris and colleagues use sophisticated statistical analysis to demonstrate statistically significant relationships between outcomes and IAF. However, one needs to know an individual's probability of an outcome for stratification and to make a decision

that avoids poor outcome. The odds ratios (ORs) reported in the article by Morris et al do not directly provide probability.

Let us examine the OR of 1.09 for mortality vs IAF, which tells us that the OR increases 9.X% per millimeter increase in IAF. A 2-mm increase in IAF thus increases the OR 1.09 for the first millimeter times 1.09 for the second millimeter, so any increase (x) in IAF OR