Original Investigation

Validation of Feasibility of Magnetic Resonance Imaging for the Measurement of Depth of Tumor Invasion in Distal Bile Duct Cancer According to the New American Joint Committee on Cancer Staging System

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Rationale and Objectives: This study aimed to develop and validate a method for measuring the depth of tumor invasion (DoI) using magnetic resonance imaging (MRI) and to investigate the diagnostic performance of the measured DoI for stratifying tumor (T) classification in patients with distal bile duct cancer according to the new American Joint Committee on Cancer staging system.

Materials and Methods: Fifty-four patients (30 men and 24 women; age range, 43–81 years) with distal bile duct cancer were enrolled. A study coordinator first developed a "provisional method" for measuring DoI on T2-weighted MRI. Subsequently, after compensating for defects, the "improved method" was developed. Two reviewers independently measured DoI and assessed its correlations with the histopathologic reference standard using intraclass correlation coefficient (ICC). The study population was grouped according to the DoI for T classification based on the new staging system for evaluation of diagnostic predictive values.

Results: The ICC values between the radiologic and the histopathologic DoI were calculated. Using the "improved method," the ICC for the coordinator's DoI was very good (ICC, 0.885), which was a significantly higher value than that obtained using the "provisional method" (ICC, 0.501, $P = .00000$); and for two reviewers' DoIs, the ICC values were good (ICC, 0.752 and 0.784, respectively). The overall accuracy of MRI for stratifying bile duct tumors using DoI was 87.0% and 85.2%, respectively.

Conclusions: This newly developed method reliably measured DoI on T2-weighted MRI and can be used for preoperative T classification of patients with distal bile duct cancer according to the new staging system.

Key Words: Bile duct neoplasms; magnetic resonance imaging; tumor staging; neoplasm invasion.

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INTRODUCTION

Bile duct carcinoma is an uncommon neoplasm that accounts for 3% of all gastrointestinal cancers worldwide (1), and distal bile duct cancer accounts for 20%–30% of all bile duct carcinomas (2). Despite advances in surgical techniques and the introduction of developed oncologic modalities, the overall prognosis of bile duct cancer remains poor. As for other gastrointestinal tumors, tumor (T) classification is a major prognostic indicator in bile duct cancer. However, several studies have reported problems with T-staging using the seventh or former editions of the American Joint Committee on Cancer (AJCC) staging system (3–7). According to these systems, the T1 and T2 stages of distal bile duct cancer are distinguished on the basis of the extent of tumor within or beyond the bile duct wall, and T2 and T3 stages are distinguished on the basis of the presence or absence of adjacent organ invasion, including invasion of the gallbladder, duodenum, and pancreas (8). However, it has been noted that the staging system using descriptive extent of tumor invasion is associated with certain problems from both histopathologic and clinical aspects. For these reasons, several studies have suggested an alternative T-staging system using the depth of tumor invasion (DoI) to overcome the problems of the old T classification system (3,4,9), and the primary tumor staging of distal bile duct cancer in the eighth AJCC staging system was changed accordingly (10). In the new staging system, the definitions of T1, T2, and T3 have been revised based on measured DoI, which is better for predicting patient outcome and allows more reproducible measurements.

Magnetic resonance imaging (MRI) and multidetector computed tomography are useful modalities for the preoperative evaluation of bile duct cancer in terms of diagnosis, characterization, localization, and staging (11). For the diagnosis of bile duct cancer, information regarding the extent of the tumor and its resectability obtained with contrast-enhanced MRI and magnetic resonance (MR) cholangiography shows a diagnostic performance similar to information obtained using multidetector computed tomography and direct cholangiography (12). However, MRI is better than computed tomography for the visualization of intraductal lesions (13) and the assessment of lateral extensions of extrahepatic bile duct cancer because of its superior contrast resolution and recent advances in MRI techniques. If the DoI of bile duct cancer can be accurately assessed using preoperative MRI, it might be used as a prognostic indicator.

The aim of this study was to develop and validate a method for measuring DoI using MRI and to investigate its diagnostic performance for stratifying the T classification of patients with distal bile duct cancer according to the new AJCC staging system.

MATERIALS AND METHODS

This retrospective study was approved by the local institutional review board, and the requirement for informed consent was waived.

Study Subjects

From January 2007 to June 2016, computerized searches of our institutions' (Korea University Anam Hospital) databases were performed, and 348 consecutive patients were found to have histopathologically confirmed extrahepatic bile duct carcinoma. Of these, 65 patients who had a bile duct tumor located distal to the bifurcation of the hepatic ducts and who had undergone upper abdominal MRI less than 4 weeks before surgery were considered for inclusion in the study. Eleven patients were excluded because of poor pathologic slide quality or poor orientation ($n = 7$); mucoepidermoid carcinoma, a rare variant of cholangiocarcinoma ($n = 1$); poor MR image quality or no available axial T2-weighted image ($n = 2$); and the impossibility of identification of a tumor on MRI because of multiple biliary stones and cholangitis ($n = 1$). Finally, 54 patients (mean age, 67.11 years; range, 43–81 years) including 30 men (mean age, 65.13 years; range, 43–81 years) and 24 women (mean age, 69.58 years; range, 54–79 years) were included in our study (Fig 1).

Histopathologic Review

One pathologist (J.Y.K., with 9 years of clinical experience in staging gastrointestinal tumors), blinded to patient information, measured the DoI of the histopathologic specimens in millimeters. All histopathologic findings were reviewed, and representative slides exhibiting the deepest tumor infiltration were selected. DoI was measured from the basal lamina of the adjacent normal mucosa to the most deeply invaded tumor foci (3,14). In cases showing an absence of adjacent normal mucosa, the DoI was measured from the top of the surface of the tumor to the deepest invasive foci as previously described by Moon et al. (6). However, measurement of DoI from the top of the surface was not performed in tumors

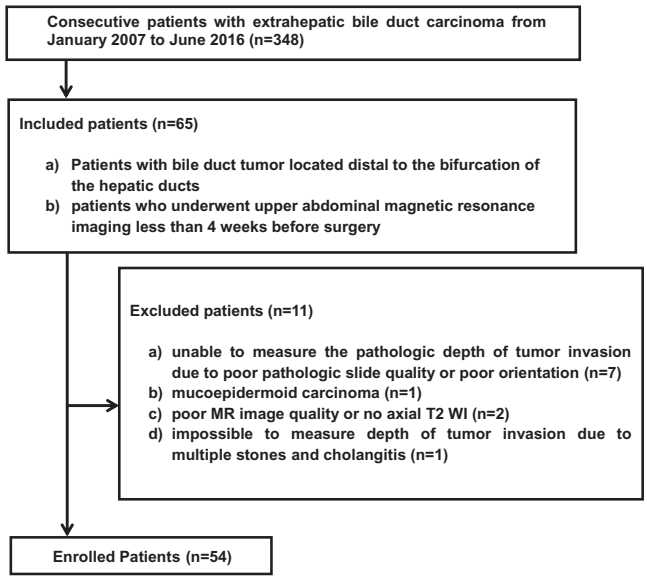

Figure 1. A flowchart of patient selection, inclusion, and exclusion.