COMPARATIVE METABOLISM OF C-14-LABELED APIXABAN IN MICE, RATS, RABBITS, DOGS, AND HUMANS

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Abbreviations: AUC, area under time curve; ADME, absorption, distribution, metabolism, and excretion; BDC, bile duct-cannulation; BMS-562247, 1-(4-methoxyphenyl)-7-oxo-6-[4-(2-oxopiperidin-1-yl)phenyl]-4,5-dihydro pyrazolo[5,4-c]pyridine-3-carboxamide; CPM, counts per minute; HPLC, high performance liquid chromatography; LC/MS, liquid chromatography/mass spectrometry; IV, intravenous; LSC, liquid scintillation counting; NMR, nuclear magnetic resonance; PK, pharmacokinetics; QTOF, Quadropole flight of time; TRA, total radioactivity
ABSTRACT

The metabolism and disposition of [14C]apixaban, a potent, reversible, and direct inhibitor of coagulation factor Xa was investigated in mice, rats, rabbits, dogs, and humans following single oral administration and in incubations with hepatocytes. In plasma, the parent compound was the major circulating component in mice, rats, dogs, and humans. O-Demethyl apixaban sulfate (M1) represented approximately 25% of the parent AUC in human plasma. This sulfate metabolite was present, but in lower amounts relative to parent, in plasma from mice, rats, and dogs. Rabbits showed a plasma metabolite profile distinct from other species with apixaban as a minor component and M2 (O-demethyl apixaban) and M14 (O-demethyl apixaban glucuronide) as prominent components. The fecal route was a major elimination pathway, accounting for >54% of dose in animals and >46% in humans. The urinary route accounted for <15% in animals and 25-28% of dose in humans. Apixaban was the major component in feces of every species and in urine of all species except rabbit. M1 and M2 were common prominent metabolites in urine and feces of all species as well as in bile of rats and humans. In vivo metabolite profiles showed quantitative differences between species and from in vitro metabolite profiles, but all human metabolites were found in animal species. Following intravenous administration of [14C]apixaban to bile-duct cannulated rats, the significant portion (approximately 22%) of the dose was recovered as parent drug in the feces, suggesting direct excretion of the drug from gastrointestinal tracts of rats. Overall, apixaban was effectively eliminated via multiple elimination pathways in animals and humans, including oxidative metabolism, and direct renal as well as intestinal excretion.
INTRODUCTION

Thromboembolic events, including acute myocardial infarction, unstable angina, deep vein thrombosis (DVT), pulmonary embolism (PE) and ischemic stroke, continue to be the leading cause of morbidity and mortality in the USA and other Western countries (Heit et al., 2005; Rosamond et al., 2007). Current therapies for the treatment and prevention of thromboembolic events, such as vitamin K antagonists (e.g., warfarin), heparin, and low molecular weight heparin (e.g., enoxaparin), are suboptimal (O'Donnell and Weitz, 2004; Wittkowsky, 2004; Campbell, 2006). The requirement for intravenous or subcutaneous injection and/or the need for careful monitoring due to the risk of excessive bleeding or unpredictable/inconsistent pharmacokinetics (PK) can complicate administration and present barriers to the use of these agents (O'Brien and Caro, 2002; Wittkowsky, 2004; Campbell, 2006). Therefore, new, orally active anticoagulants with predictable PK profiles are needed that can be administered with a reduced need for monitoring.

Factor Xa is a key serine protease in the coagulation cascade and is a promising target enzyme for new therapeutic agents for the treatment and prevention of arterial and venous thrombosis (Kaiser, 2002; Samama, 2002; Walenga et al., 2003). Specifically, factor Xa plays a critical role in blood coagulation, serving as the juncture between the extrinsic (tissue factor initiated) and intrinsic (surface activation and amplification) systems (Mann et al., 2003). Factor Xa forms the prothrombinase complex with phospholipids, calcium ions and a co-factor, factor Va, which is responsible for the generation of thrombin from prothrombin. Although factor Xa inhibition attenuates the generation of thrombin, it does not affect thrombin activity, thereby preserving hemostasis, which, in clinical terms, may translate to efficacy with lower bleeding risk (Comp, 2003; Kubitza and Haas, 2006). Indeed, studies have shown that factor Xa inhibitors interrupt...
thrombus growth in large blood vessels under low shear (venous thrombosis) and high shear (arterial thrombosis) conditions, with minimal disruption of normal hemostasis, suggesting the suitability of such agents in the management of both venous and arterial thromboembolic disorders (Orvim et al., 1995; Shimbo et al., 2002). Clinical proof-of-principle for the efficacy and potential of factor Xa inhibitors is available from fondaparinux, an indirect factor Xa inhibitor (Walenga et al., 1988; Samama and Gerotziafas, 2003; Simoons et al., 2004; Wong et al., 2006; Yusuf et al., 2006; Yusuf et al., 2006; Schumacher et al., 2007) [prescribing information for Atrixtra (fondaparinux sodium) injection, http://gsk.com/products/assets/us_atrixtra.pdf].

Apixaban is a promising oral anticoagulant in the late-stage clinical development for the prevention and treatment of venous thromboembolism, stroke prevention in atrial fibrillation, and secondary prevention in acute coronary syndrome. It is a potent, oral, reversible, selective and direct factor Xa inhibitor, which inhibits both free and prothrombinase-bound factor Xa activity, and shows considerable efficacy in the prevention of arterial and venous thrombosis at doses that preserved hemostasis in rabbits (Pinto et al., 2007; Wong et al., 2008). It is also effective and safe for the prevention and treatment of venous thrombosis in humans (Lassen et al., 2007; Büller et al., 2008). Positive preliminary results from a Phase II clinical trial evaluating the prevention of venous thromboembolic events (VTE, asymptomatic and symptomatic DVT and non-fatal symptomatic PE) demonstrate the potential benefit of this agent versus standard therapy in anticoagulation monotherapy treatment in humans (Lassen et al., 2007).

Apixaban was well absorbed in rats and dogs (mean bioavailability of 34-80%, respectively). The mean volume distribution of apixaban was 0.31 and 0.2-0.29 l/kg in rats and dogs, respectively. The systemic clearance of apixaban was low, <10% and <3% of hepatic blood flow
in rats and dogs, respectively (Shantsila and Lip, 2008). Metabolic pathways of apixaban in humans included O-demethylation, hydroxylation, and O-demethylation followed by sulfation (Raghavan et al., 2009). This study was conducted to evaluate the comparative metabolic disposition of apixaban in different species. The study included an in vitro component, in which hepatocytes of mice, rats, dogs, monkeys, and humans were incubated with $^{14}$C-apixaban, and an in vivo component, in which mice, rats, rabbits, dogs, and humans were dosed orally with $^{14}$C-apixaban and samples of plasma, urine, feces, and bile were collected and analyzed for radioactive components. In addition, the elimination properties of $^{14}$C-apixaban were studied in BDC rats following intravenous administration.

MATERIALS AND METHODS

Materials
Apixaban (BMS-562247, purity >99%) and $^{14}$C-apixaban were synthesized at Bristol-Myers Squibb. The radiochemical purity was >98.6% for $^{14}$C-apixaban. The metabolite standard M2 (O-demethyl apixaban) and its sulfate conjugate M1 were also prepared at Bristol-Myers Squibb. Formic acid and ammonium hydroxide were purchased from Thermo Fischer Scientific Co. (Waltham, MA). Deepwell LumaPlate™-96-well plates were purchased from PerkinElmer Life and Analytical Sciences (Waltham, MA). Ecolite™ liquid scintillation cocktail was purchased from MP Biomedicals, Inc. (Irvine, CA). All other organic solvents and reagents were of high-performance liquid chromatography (HPLC) grade.

Fresh hepatocytes from mice (male ICR/CD-1) and rats (male Sprague-Dawley) were prepared. Cryopreserved hepatocytes from dogs (male beagle) were prepared by Tissue Transformation Technologies (Franklin Lakes, NJ). Cryopreserved hepatocytes from monkeys (male cynomolgus) and humans (male and female) were obtained from Celsis In Vitro Technologies,
Inc. (Baltimore, MD). Hepatocytes were stored in liquid nitrogen before use. Pooled human liver microsomes (HLM, 22 donors) and Supersomes® (membranes from insect cells transfected with baculovirus containing cDNA of human CYP3A4) were purchased from Gentest, BD Biosciences Corporation (Woburn, MA).

**Study Subjects, Dosing, and Sample Collection**

All animal housing and care conformed to the standards recommended by the Guide for the Care and Use of Laboratory Animals. Animal rooms were maintained on a 12-hour light and dark cycle. The human study was performed in accordance with the principles of the Declaration of Helsinki and its amendments, and the study protocol was approved by the Institutional Review Board and Radiation Safety Committee at the investigational site. All subjects were in good health and gave written, informed consent to participate in the study.

All blood samples were collected into tubes containing K$_2$EDTA. These samples were placed on ice immediately after collection and centrifuged within 30 minutes of collection to harvest plasma.

The $[^{14}\text{C}]$apixaban oral dose formulations were prepared in 0.5% (v/v) Tween 80 in Labrafil® at 6 mg/mL (30 μCi/mL) for mouse and rat, at 6 mg/mL (9 μCi/mL) for rabbit, at 2.5 mg/mL (12.5 μCi/mL) for dog, and at 2 mg/mL (10 μCi/mL) in PEG-400:ethanol (85:15, v/v) for humans. The IV dosing solution was prepared by dissolving 30 mg of $[^{14}\text{C}]$apixaban to 7 mL of vehicle containing 10% dimethyl acetamide and 30% propylene glycol in water.

**Mouse**

Male CD-1 mice (25-35 g) were obtained from Charles River Laboratories (St. Constant, Quebec, Canada), fed with Certified High Fiber Rodent Diet 5002 (LabDiet®, PMI® Nutrition International, Purina Mills), and provided fresh filtered tap water *ad libitum*. Mice were fasted
for approximately 2.5 to 3.5 hours before dosing. Each animal received an oral gavage dose of 30 mg/kg (150 μCi/kg) of \[ ^{14}C \]apixaban. Food was returned to the animals about 2 to 4.5 hours after dosing. Urine and feces were collected from five mice at 12-hour intervals over 0–48 hours after dosing. Terminal blood samples (five mice per time point) were collected via cardiac puncture under carbon dioxide anesthesia from mice at 1, 4, 12, 24 and 48 hours.

**Rat**

Male BDC and intact Sprague-Dawley rats (250-280 g) were obtained from Harlan Laboratories, Inc. (Indianapolis, IN), fed with Certified High Fiber Rodent Diet 5002, and provided fresh filtered tap water *ad libitum*. Rats were fasted overnight before dosing. Intact animals and those previously prepared with bile-duct cannulas each received an oral gavage dose of 30 mg/kg (150 μCi/kg) of \[ ^{14}C \]apixaban. Urine, bile, and feces were collected at 12-hour intervals over 0–48 hours after dosing from three BDC rats. Urine and feces samples were collected at 24 hour intervals over 0–168 hours after dosing from three intact rats. Terminal blood samples were collected via cardiac puncture under carbon dioxide anesthesia from three intact rats per time point at 1, 4, 12, 24 and 48 hours.

Three BDC and 3 intact rats were each given an IV infusion of \[ ^{14}C \]apixaban in dimethyl acetamide and propylene glycol solution at 0.1 mL/min for 10 min (15 mg/kg, 30-45 μCi/rat, S.A. 7.6 μCi/mg). Bile, urine, feces and gastrointestinal tract (GI) samples were collected from BDC rats from 0-24 h intervals after dosing. A bile salt solution (18 mg/mL cholic acid and 1.1 mg/mL sodium bicarbonate in saline, pH 7.2) was infused via the duodenal cannula at 1 mL/h for BDC rats. Urine and fecal samples were collected from intact rats over 24 h periods. The plasma samples were collected at 24 h post-dose.
Rabbit

Three female New Zealand rabbits (2.5 kg) each received a single oral gavage dose of $[^{14}C]$apixaban at a dose level of 30 mg/kg (45 μCi/kg). The animals were fasted for 11 hours before dosing, fed daily with LabDiet® Certified Hi-Fiber Rabbit Diet 5325 (PMI® Nutrition International), and provided fresh filtered tap water ad libitum. The actual amount of dosing solution administered to each rabbit was determined by weighing the loaded dosing syringe before dose administration and the emptied syringe after dose administration. Urine and feces samples were collected over 0-48 h at 12 h intervals after dosing. Blood samples (4 mL) were collected at 1, 4, 12, 24, and 48 h into tubes containing potassium EDTA.

Dog

Non-naive male beagle dogs (7-11 kg) were taken from the Charles River Laboratories test facility. The animals were fed with Canine Diet #5006 (LabDiet®, PMI® Nutrition International) and provided water ad libitum. Dogs were fasted overnight before dosing. Each animal received an oral dose of 5 mg/kg (25 μCi/kg) of $[^{14}C]$apixaban followed by a 5 to 10 mL water rinse through the gavage tube. Urine and feces were collected at 24-hour intervals from three animals over 0–168 hours after dosing. Blood samples were collected via the cephalic vein at 1, 4, 12, 24 and 48 hours.

Human

A total of 10 healthy male subjects, aged 18 to 45 years, participated in the study (Raghavan et al., 2009). After at least an 8 hour overnight fast, each subject received a single oral 20 mg (108.8 μCi) dose of $[^{14}C]$apixaban as a solution in PEG-400/ethanol (85:15, v/v). Blood samples (10 mL each) for biotransformation analysis were drawn at 1, 4, 12, 24 and 48 hours post-dose. Urine and feces were collected over 24-hour intervals from six subjects for 10 days. Bile samples
were collected during 3 to 8 hours post dose under suction using a weighted oral-gastro-duodenal tube in the second group of four subjects as described previously (Wang et al., 2007). At 7 hours post dose a 20 ng/kg IV dose of cholecystokinin carboxyl-terminal octapeptide (Kinevac®) was infused over 5 minutes to stimulate gallbladder contraction and enhance bile flow.

**Incubation of [14C]Apixaban with Hepatocytes**

[14C]Apixaban, at concentrations of 1 and 10 µM in incubation buffer media, was separately incubated with mouse, rat, dog, monkey, and human hepatocytes in duplicates. Incubations were carried out in Costar® 24-well cell culture plates with each well containing 0.5 or 1.0 mL of the incubation mixture. The cell concentration in the final incubation mixture was approximately 1 x 10⁶/mL viable cells. All incubations were conducted in an incubator maintained at 37°C, in an atmosphere consisting of 95% air/5% CO₂, and humidity maintained at 95%. Additional incubations at a concentration of 100 µM of apixaban with dog and rat hepatocytes for 4 hours were conducted for metabolite characterization and identification.

Incubations at 100 µM of coumarin and 7-ethoxycoumarin were used as positive controls. At the end of the 4-hour incubations, the [14C]apixaban incubation mixtures at the same concentration were pooled and mixed with two volumes of ice-cold acetonitrile, which was followed by centrifugation at 2,000xg for 10 minutes. The supernatants were individually transferred to another set of pre-labeled 15 mL conical centrifuge tubes. Each well was rinsed with 1.0 mL of acetonitrile(buffer (2:1). The rinse solution was used to wash each respective protein precipitate, followed by centrifugation. The supernatants were combined duplicate aliquots (20 µl) of each sample were assayed by liquid scintillation counting (LSC). A portion of the acetonitrile extracts from each hepatocyte incubation was evaporated to dryness by a rotary evaporator or pre-treated
by solid phase extraction (C18). The remaining residues were reconstituted in an appropriate volume of methanol:water (2:1, v/v) for HPLC analysis.

**Radioactivity Analysis**

The levels of total radioactivity in plasma, urine, bile and fecal homogenate were determined by LSC after an aliquot of each sample was combusted. Fecal samples were thawed and water/ethanol (50:50, v/v) solution was added to form an approximate 20% (w/w) feces/solvent homogenate. The volume of bile and urine, and weight of feces collected over each interval and the concentrations of radioactivity in the corresponding samples were used to calculate the cumulative percent of the administered dose recovered in the bile, urine and feces for the estimation of biliary, urinary, and fecal elimination of radioactivity.

**Sample Preparation for Biotransformation Analysis**

Pooled plasma samples (at 1, 4, 12, 24, and 48 hours) were prepared separately by mixing an equal volume (0.5 mL) of plasma sample from each subject. For rabbits, only 1- and 4-hour plasma contained appreciate levels of radioactivity for extraction and profiling. Each pooled plasma sample was extracted in duplicate at each time point by addition of 4 mL of acetonitrile/methanol (1:1, v/v) to 1 mL of plasma while the sample was mixed on a vortex mixer. After centrifugation at 2000 x g for 1 hour, each supernatant fraction was removed and saved, while the precipitate was re-suspended in 2 mL of acetonitrile and 1 mL of methanol. Following centrifugation of the precipitate mixture for 30 min at 2000 x g, the supernatant fraction was removed and combined with the first supernatant; the precipitate was re-suspended in 2 mL acetonitrile. The combined supernatant fractions were evaporated to dryness under nitrogen and reconstituted in 0.15 mL of acetonitrile and 0.05 mL of methanol. Following centrifugation at 2000 x g for 5 min, a 0.06–0.1 mL portion of supernatant was subject to HPLC
analysis. Each pooled urine and bile sample was thawed at room temperature and mixed on a vortex-mixer. Following centrifugation at 2000 x g for 5 min, a 0.1 mL portion of each urine sample was subject to HPLC analysis. Bile samples were diluted with water (1:1, v/v) and a 0.03 - 0.1 mL portion was subject to HPLC analysis followed by ion trap analysis or quadrupole time of flight mass spectrometry analysis (Q-TOF MS, Waters, Beverly, MA).

Each pooled fecal homogenate sample (0.5 mL) was extracted in replicates by addition of 1.5 mL of methanol/acetonitrile (1:2, v/v) while the sample was mixed on a vortex mixer. After centrifugation at 2000 x g for 30 min, the supernatant fraction was removed and saved; the precipitate was resuspended and the extraction was repeated a second time. The combined supernatant was evaporated to dryness under nitrogen and reconstituted in 0.15 mL of methanol. Following centrifugation at 2000 x g for 5 min, a 0.04 mL portion of supernatant was injected into the HPLC. The average column recovery from the replicate (n=2) samples was calculated relative to the total radioactivity injected.

**Metabolite Profiles, Identification, and Quantification**

**Metabolite Profiles**

Sample analysis by HPLC was performed on a Shimadzu (Kyoto, Japan) LC-10AT system equipped with a photodiode array ultraviolet (UV) detector. An Ace 3, C18 (3 μm), 150 x 4.6 mm column (MacMod, Chaddsford, PA) was used, and the mobile phase flow rate was 0.7 mL/min. The retention times of reference standards were confirmed by their UV spectral analysis. The HPLC solvent system was a gradient of two solvents 0.4% formic acid in water, pH 3.2 (A) and 100% acetonitrile (B). The gradient for elution was 0% B for 3 min, 0-10% B in 2 min, 10-25% B in 15 min, hold 25% B for 30 min, 25-50% B in 10 min and 50-100% B in 5 min, 100% B for 5 min. The relative retention times of apixaban and its metabolites were
sensitive to minor variations in buffer preparations, between individual columns, and in sample preparations. However, a portion of HPLC elute was always diverted to liquid chromatography/MS (LC/MS) for confirmation of metabolites. For quantitation of radioactivity, HPLC effluent was collected into 96-deep-well luma-plates in 0.26 min intervals using a Gilson Model 204 fraction collector (Gilson Medical Electronics, Middleton, WI). The plates were dried in an Automatic Environmental Speed Vac (Savant) and counted for radioactivity for 20 minutes (counts per minute, CPM) using a Packard TopCount NXT microplate scintillation and luminescence counter (PerkinElmer Life Sciences, Inc., Waltham, MA). Radiochromatograms were reconstructed from the TopCount data using Microsoft® Excel software. For each injection, the average CPM value from a baseline section of 2–3 min in the chromatogram was subtracted from the CPM value of each fraction. Biotransformation profiles were prepared by plotting the CPM values against time-after-injection. Radioactivity peaks in the biotransformation profiles were reported as a percentage of the total radioactivity collected during the entire HPLC run.

**Metabolite Identification and Quantification**

Bile, urine and the extracts of pooled plasma and fecal samples were analyzed by LC/MS using a Finnigan LTQ ion trap mass spectrometer (Thermo Finnigan, San Jose, CA). LC/MS analysis was performed with an ESI probe in the positive ion mode. The HPLC eluate was directed to the mass spectrometer through a valve set to divert the flow from 0 to 5 min. The eluate flow was directed to the mass spectrometer from 5 min until the end of the HPLC run. The capillary temperature for analysis was set to 230°C. The nitrogen gas flow rate, spray current, and voltages were adjusted to give the maximum sensitivity for apixaban. Bile and plasma samples were also analyzed using Q-TOF/MS (Waters, Beverly, MA). The collision energy used for MS and MS/MS were 10 and 25 V, respectively. The mass reference was Leucine Enkephalin.
Incubation, Isolation and NMR Analysis of M7

$[^{14}C]$Apixaban at a concentration of 250 $\mu$M (1 $\mu$Ci/mg) was incubated with cDNA-expressed CYP3A4 Supersomes® at a final enzyme concentration of 200 pmol P450/mL in 0.05 M phosphate buffer (pH 7.4). NADPH was added to the incubation mixture at a final concentration of 1.2 mM. The total volume of the incubation mixture was 37.5 mL. Aliquots of 2.5 mL were transferred into 20 mL glass vials. The mixture was incubated in a water bath at 37°C for 1 hour. At the end of the incubation period, acetonitrile (one volume) was added to each sample, the mixture was vortexed and centrifuged for 5 min at 2000 xg. The supernatant from each vial was transferred to a 50 mL polypropylene centrifuge tube and concentrated to approximately 2.5 mL. Portions of 250 $\mu$L aliquots of samples were injected and the metabolite M7 peak eluate collected into a tube. The eluate was then evaporated under a stream of nitrogen and reconstituted with 0.5 mL of deuterated acetonitrile and vortexed. A 20-$\mu$L sample was mixed with 15 mL of scintillation cocktail and counted on a scintillation counter for 10 min; the amount of metabolite M7 was calculated based on the amount of radioactivity and specific radioactivity. The remaining sample was evaporated under nitrogen and reconstituted again with 300 $\mu$L of deuterated acetonitrile. After evaporation, approximately 80 $\mu$g of the metabolite was dissolved in 200 $\mu$L of CD$_3$CN and transferred into a 3 mm nuclear magnetic resonance (NMR) tube for analysis.

Proton NMR was performed on a Bruker DRX-600 MHz NMR spectrometer equipped with an indirect detection 5 mm TXI Bruker Cryo-probe for 1D- and 2D-H NMR. The temperature was controlled at 30°C. The WET solvent suppression system was used to remove residual HOD and CH$_3$CN signals. The free induction decay (FID) file was transferred to a desktop PC operating on Windows NT and processed with a NMR processing software version 3.5 from Advanced
Chemistry Development Inc. (Toronto, ON, Canada). All chemical shifts are reported in ppm relative to tetramethylsilane.

RESULTS

Excretion of Radioactive Dose

Following oral administration, the recovery values of radioactive dose in urine and feces (mice, rats, rabbits, dogs and humans), and in bile (rats and humans) are shown in Table 1. In each species, total recovery of radioactive dose was >77%, indicated good mass balance (Roffey et al., 2007), except rabbits in which approximately 1.8 and 54.3% of dose was recovered in 0-48 h collection of urine and feces, respectively. In all species including BDC rats and humans with bile collections, the majority of the recovered radioactive dose was present in feces. Recovery of radioactivity in urine ranged from 1.8 to 29% across species and was similar for rats and humans with and without bile collection. Humans appeared to show a higher percent of dose eliminated from urine than animal species. Only about 2.5% of the dose was recovered in bile of rat and human during limited collection periods.

Male mice excreted approximately 85% of the administered dose within 12 hours after oral dose of \[^{14}\text{C}]\text{apixaban}\) (approximately 71% in feces and 14% in urine). In male rats and dogs, approximately 78 and 86%, respectively, of the administered dose was excreted within 48 hours after oral dose of \[^{14}\text{C}]\text{apixaban}\), with approximately 6.7 and 12.6% excreted in urine. In humans, approximately 23% of the dose was excreted in urine within 48 hours of dosing, and approximately 45% of dose was excreted in feces within 96 hours post-dose. Urinary dose recovery seemed to be lower in rabbits than other species.
Metabolic Profiles of [14C]Apixaban in Plasma, Urine, Bile and Feces

Apixaban metabolite occurrence and identities are listed in Table 2. Profiles and tabulations of the distribution of radioactivity in plasma, urine and feces for samples obtained without bile collection are listed in Tables 3 and 4. The identity of apixaban and the metabolites in different matrices were verified by LC/MS together with radioactivity detection.

Plasma

The relative distribution of radioactive metabolites in plasma after oral administration of [14C]apixaban is summarized in Table 3 and supplemental Figure S1A. The percent extraction of radioactivity in the all plasma samples was >85%. Apixaban was the major radioactive component in plasma from mice, rats and dogs, but a minor component in rabbits. Metabolite M1 was not detected in mouse plasma, was present at only low relative abundance (<1% of radioactivity) in plasma from rats and dogs, and a prominent component in rabbit plasma. Its metabolic precursor, M2 (O-demethyl apixaban), was a prominent metabolite in plasma from mice, rats, rabbits, and dogs. Other animal plasma metabolites were M7, M13, and M14 as minor components in mice, M4 and M7 as minor components in rats, and M14 as a major component in rabbits. For comparison, apixaban and metabolite M1 (O-demethyl apixaban sulfate) were the major radioactive components in human plasma. The relative abundance of M1 increased from 2 to 28% of the radioactivity in the 1 h versus 12 h human plasma samples.

Urine

The relative distribution of radioactive metabolites in urine after oral administration of [14C]apixaban is summarized in Table 4 and supplemental Figure S1B. Apixaban constituted the most of the radioactivity in urine from mice, rats and dogs, but M2 was the major component in rabbit urine. No metabolites including M2 and M13 in mice, M2 and M4 in rats, M1, M14 and
M16 in rabbits, M2, M7, M4, and M8 in dogs accounted for more than 1% of the dose in urine from these species. In human urine, apixaban constituted most of the radioactivity (22.5% of the dose), along with small amounts of M1 and M7 (each less than 2% of the dose).

**Feces**

The relative distribution of radioactive metabolites in feces after oral administration of \[^{14}\text{C}]\text{apixaban}\) is summarized in Table 4 and supplemental Figure S1C. The percent extraction of radioactivity from fecal samples was >80%. The most abundant radioactive compounds found in feces of mice, rats, rabbits, and dogs were unchanged apixaban followed by metabolites M2 and M7. In human feces, unchanged apixaban and metabolite M2 (\(O\)-demethyl apixaban) were the major radioactive components, representing 34 and 12% of the dose, respectively. Metabolites M1, M4, M7, and M13 were also found in human feces at amounts representing 1 to 4% of the dose.

**Bile**

The relative distribution after oral dose of \[^{14}\text{C}]\text{apixaban}\) in pooled bile of rat and human is shown in the supplemental Figure S2. Since <3% of the radioactive dose was recovered in bile, the results are not shown in a tabular form. The most abundant radioactive compounds in rat bile were unchanged apixaban and metabolites M1 and M2, which occurred at approximately equal proportions. It is possible that M1 is present in rat bile but not rat feces because it was hydrolyzed to M2 in the intestine or feces. In human bile the major radioactive components were unchanged apixaban and metabolites M1, M7 and M10. Metabolites M2 and M13 were also present in lesser quantities. The difference between the profiles of radioactivity in human feces and bile probably resulted from the partial hydrolysis of the sulfate conjugates M10 to M13 and M1 to M2 by intestinal contents in feces.
Elimination of [14C]Apixaban in Rats Following IV Administration

The disposition of [14C]apixaban was determined in intact and bile duct-cannulated (BDC) rats (15 mg/kg) after intravenous administration (IV). Urinary, fecal, and gastrointestinal (GI) recovery (0-24 h) of radioactivity was 20.7, 12.7, and 1.7%, of the dose, respectively, from intact rats. Urinary, biliary, fecal, and GI recovery of radioactivity was 46.6, 23.0, 24.9, and 0.4%, respectively, from the modified rats. The parent was the major radioactive component in urine, bile, and feces in both intact and BDC rats. The parent compound represented approximately 22% of the dose in feces of BDC rats, following IV administration, suggesting direct excretion of apixaban from GI tracts in rats. M2, M4, and M7 were observed metabolites in feces of intact rats. The biliary metabolite profile of BDC rats following IV administration was similar to that of BDC rats following oral administration of [14C]apixaban and those metabolites included M1, M2, M7, and M9 as major ones and M3 and M4 as minor ones (Figure 1).

In Vitro Metabolism

Control incubations demonstrated the viability of the hepatocyte preparations as the activities for oxidative and conjugative metabolism of model substrates matched historical levels. Values for percent of substrate metabolized at the end of the incubation period for hepatocytes from mice, rats, dogs, monkeys and humans, respectively, were 16, 11, 83, 92 and 90%, respectively, using 7-ethoxycoumarin as an oxidation substrate and 29, 64, 76, 99 and 83%, respectively, using 7-hydroxycoumarin as a conjugation substrate.

Apixaban metabolite structures are shown in Table 2 and the distribution of the metabolites in the hepatocyte incubations is shown in Table 5. Overall, [14C]apixaban showed a low rate of in vitro metabolism. The metabolite profiles of all five species were qualitatively similar, with unchanged apixaban remaining as the major radioactive component. Seven radioactive
metabolites, designated M1 to M7, were characterized or identified in vitro. M6 was proposed as a carboxylic acid derivative resulting from hydrolysis of the amide bond and was only observed in the mouse and rat hepatocytes but not in any other hepatocytes or any in vivo matrices. Six human hepatocyte metabolites, M1 to M5 and M7, were all found to be present in animal hepatocyte incubations. The major in vitro metabolic routes for apixaban included O-demethylation (M2) followed by sulfate conjugation (M1) and monooxidation to form hydroxy apixaban (M4 and M7).

**Identification of Apixaban Metabolites**

Metabolites were characterized by LC/MS and LC/MS/MS analyses from plasma, urine, bile, and feces of all species. The proposed prominent metabolic pathways of apixaban are shown in Figure 2. The proposed structures of [14C]apixaban metabolites from the in vitro and in vivo samples in which they were found are shown in Table 2.

**Apixaban**

Apixaban showed a molecular ion [M+H]+ at m/z 460 and fragment ions at m/z 443, 417, 402, 199, and 184 in LC/MS and MS/MS analyses.

**Metabolites M2 and M1**

M1 and M2 showed molecular ions [M+H]+ at m/z 526 and 446 and major fragment ions at m/z 446 and 429, respectively. As described previously (Raghavan et al., 2009), M1 was identified as a sulfate conjugate of M2. Metabolite M2 was identified as O-demethyl apixaban.

**Metabolite M3**

M3 showed a molecular ion [M+H]+ at m/z 492 and major fragment ions at m/z 474 and 378. M3 was consistent with oxidation followed by lactam ring opening (Table 2). The major fragment ion at m/z 378 was consistent with the structure of 1-(4-hydroxyphenyl)-7-oxo-6-(4-(2-
oxopiperidin-1-yl)phenyl) amine. Upon HPLC analysis on a reverse-phased C18 column, the metabolite had a much shorter retention time with a mobile phase at pH 6.8 than at pH 3.2, supporting a carboxylic acid moiety in this metabolite. Based on the HPLC retention time and MS fragmentation patterns, M3 was proposed as a metabolite resulting from oxidation followed by ring opening.

**Metabolites M4, M7, and M9**

Metabolites M4, M7, and M9 showed a molecular ions [M+H]⁺ at m/z 476, 16 amu higher than apixaban, suggesting these were products of monooxidation. M4, M7, and M9 had fragment ions at m/z 459, 441, 415, 371, 199, and 177 in the MS² spectrum and a characteristic fragment ion at m/z 199 in the MS³ spectrum for the proposed fragment ion shown in the supplemental Figure S3A,B,C. Based on the retention time and LC/MS/MS fragmentation pattern, M4, M7, and M9 were identified as isomers of hydroxylated apixaban. A hydrogen exchange experiment was conducted with M7. LC/MS analysis of M7 after H/D exchange yielded [M+D]⁺ at m/z 480, an increase of 4 amu to its molecular ion, indicating that M7 contained one additional exchangeable proton in addition to two exchangeable protons in apixaban. This result further supported that M7 contained a hydroxyl group.

Metabolite M7 (approximately 80 μg) was generated and isolated from a large incubation of [¹⁴C]apixaban in a cDNA-expressed CYP3A4 incubation. The site of hydroxylation was determined by proton-NMR analysis. The proposed structure based on the NMR data was consistent with hydroxylation at Carbon-30. Comparing the aliphatic region of the 1D ¹H NMR spectrum of the metabolite with that of the parent compound, the resonance for the chemical shift of the signal for the methylene group at position 30 moved downfield from 1.90 to 4.24 ppm and its integration changed from two to one proton (Figure 3). The coupling pattern in the double
quantum filtered correlation spectroscopy experiment confirmed this hydroxylation at C30. The cross peak between the protons 28, 29, and 31 are labeled as regions A, B, and C.

**Metabolite M5**

M5 showed a molecular ion [M+H]** at m/z 478 and major fragment ions at m/z 458, 432, and 2342. M5 was consistent with lactam ring opening (Table 2). The major fragment ion at m/z 378 was consistent with the structure of 1-(4-hydroxyphenyl)-7-oxo-6-(4-(2-oxopiperidin-1-yl)phenyl) amine. Upon HPLC analysis on a reverse-phased C18 column, this metabolite had a much shorter retention time with a mobile phase at pH 6.8 than at pH 3.2, supporting a carboxylic acid moiety in this metabolite. Based on the HPLC retention and MS fragmentation patterns, M5 was proposed as a metabolite resulting from lactam ring opening.

**Metabolite M6**

M6 showed a molecular ion [M+H]** at m/z 461, one amu higher than the parent, suggesting loss of a nitrogen as judged by the nitrogen rule. The major fragment ion was at m/z 417, consistent with loss of 44 amu, a carboxylic acid moiety. These data are consistent with amide hydrolysis of apixaban (Table 2). In addition, upon HPLC analysis on the reverse-phased C18 column, this metabolite had a much shorter retention time with a mobile phase at pH 6.8 than at pH 3.2, supporting a carboxylic acid moiety in this metabolite. Based on these HPLC retention and fragmentation patterns, M6 was proposed as a carboxylic acid resulting from amide hydrolysis.

**Metabolite M13 and M8**

M13 and M8 showed molecular ions [M+H]** at m/z 462, 16 amu higher than M2 by LC/MS. The addition of 16 amu from the protonated molecular ion of m/z 446 suggests that M13 is hydroxylated O-demethyl apixaban. The fragmentation ions of M8 were at m/z 445, 419, 401,
363, 333, and 185 (m/z at 185 was a characteristic fragment ion for O-demethyl apixaban) (Raghavan et al., 2009). Accurate mass measurement of M13 gave a molecular ion of 462.1777, and a derived formula of C_{24}H_{24}N_{5}O_{5}. The difference between the measured mass and the theoretical mass was –1.3 mDa. These data supported that M8 and M13 were isomers of hydroxylated O-demethyl apixaban.

**Metabolite M10**

Metabolite M10 showed a molecular ion [M+NH\(_4\)]\(^+\) at m/z 559 which was 80 amu higher than M13 by accurate mass LC/MS. Accurate mass measurement of M10 gave a molecular ion of 559.1628, and a derived formula of C\(_{24}\)H\(_{27}\)N\(_6\)O\(_8\)S. The difference between the measured mass and the theoretical mass was –1.7 mDa. The metabolite was proposed as a sulfate conjugate of hydroxylated O-demethyl apixaban.

**Metabolite M14**

M14 showed a molecular ion [M+H]\(^+\) at m/z 622, and LC/MS/MS analysis showed a product ion at m/z 446. The loss of 176 from the protonated molecular ion of m/z 622 suggests that M14 is a glucuronide of M2. Based on the retention time and LC/MS/MS fragmentation, M14 was proposed as a glucuronide of O-demethyl apixaban.

**DISCUSSION**

This study reports the comparative disposition and *in vitro* and *in vivo* metabolic profiles of [\(^{14}\)C]apixaban in mice, rats, rabbits, dogs, and humans. Animal species used for toxicity testing of apixaban were used for these metabolism studies. Metabolism of apixaban in hepatocyte incubations appeared to be slow and the relatively low rate of turnover in hepatocytes was consistent with the low clearance of apixaban in corresponding species (Raghavan et al., 2009; Shantsila and Lip, 2008). Metabolism of apixaban in human hepatocytes produced primarily an
$O$-demethylation metabolite (M2), a sulfate metabolite (M1), and a hydroxylated metabolite (M7). Similar metabolites were produced in incubations of apixaban with hepatocytes from animal species (mouse, rat, dog, or monkey). *In vivo*, prominent oxidative metabolic pathways for apixaban were $O$-demethylation to form M2 and hydroxylation to form M7 and M4 in all species. The glucuronide of $O$-demethyl apixaban (M14) was a circulating metabolite in plasma of mouse but not detected in the mouse urine or feces probably because of low concentration of this metabolite in mouse excreta. Different from rat, dog, or human, the rabbit showed that the glucuronide of $O$-demethyl apixaban (M14) was a prominent component in plasma. The significant amount of this glucuronide was found in the rabbit urine samples although potential intestinal hydrolysis might underestimate the amount of this glucuronide in feces. The glucuronidation pathway for metabolism of apixaban was only found in the mouse and rabbit. In addition, the minor hydroxylation metabolite M9 were only detected in the mouse and rat and hydroxy $O$-demethyl metabolite M8 was only detected in the rat and dog. The metabolism of apixaban *in vivo* was more complicated than that seen *in vitro* with hepatocytes in terms of relative abundance and sequential metabolism. For humans, additional oxidative (formation of M13) and sulfate conjugation pathways (formation of M10) were found *in vivo* samples. Also, the presence of a major circulating human metabolite (M1) would not have been predicted from the *in vitro* results. The major *in vivo* metabolic pathways for apixaban were qualitatively similar across species but quantitatively different between species. There were sequential metabolites such as M8, M10, M13, and M14 were not detected in the *in vitro* incubations, yet there were also very minor *in vitro* metabolites M5 and M6 involving in the lactam-ring opening or amide hydrolysis that were not identified *in vivo* probably due to very low quantities of these metabolites formed *in vivo*. The *in vitro* metabolite M3 was only found in the rat and dog.
O-Demethyl apixaban sulfate (M1) was a second major radioactive component in human plasma following oral administration. This metabolite was found at much lower abundance relative to parent in the plasma of mouse, rat or dog. It is unclear as to what drives the difference in disposition and makes this metabolite a prominent circulating metabolite in humans, but not in animals as all species were capable of the demethylation and sulfate conjugation reactions based on the in vitro data (Wang et al., 2009). Also, M1 was a prominent metabolite in rat bile. Metabolites M1 and M2 were tested to be inactive factor Xa inhibitors (Wang et al., 2009). Although M1 was disproportionately circulating in humans compared to animal species, no additional safety testing was needed because it was a stable and inactive conjugation metabolite (Food and Drug Administration Guidance for Industry: Safety Testing of Drug Metabolites. February 2008).

Based on the radioactivity profiles of urine, feces and bile, direct intestinal and urinary excretion as well as oxidative metabolism appeared to be important routes of elimination for apixaban in rats. Following intravenous administration of [14C]apixaban to bile-duct cannulated rats, the large portion (approximately 22%) of the dose recovered as parent drug in the BDC rat feces suggests direct excretion of the drug through the gastrointestinal tracts as an important elimination pathway of apixaban in rats. The importance of the gastrointestinal excretion of apixaban in other species is not known at this time. The literature has accumulated evidence to suggest that direct intestinal secretion may play a major part in elimination of a number of structurally diverse drugs including digoxin, taxol, and doxorubicin (Garner et al., 2008; Merino et al., 2005; Mayer et al., 1996; Rabbaa et al., 1996; Sparrenboom et al., 1997; van Asperen et al., 2000). Although direct intestinal excretion was not commonly documented in humans due to the difficulty in making this assessment in humans, apixaban was demonstrated to show a
significant level of direct excretion from gastrointestinal tracts through a bile-cannulation study in rats.

The in vivo analysis showed that the parent compound was the major drug-related component in plasma of mouse, rat, dog and human after oral administration of apixaban. In contrast, apixaban was only detected in early time points in rabbits after oral administration and quickly cleared from the circulation. Apixaban had a very poor oral bioavailability (of approximately 3%) in rabbits. The systemic clearance of apixaban was also high in the rabbit (2.55 L/h/kg representing approximately 61% of hepatic blood flow). This pharmacokinetic profile in rabbit was very different from that in the rat, dog, and human in which apixaban showed low clearance (representing <10, <3, and <4% of hepatic blood flow, respectively), low volume of distribution, and good oral bioavailability (34, 88, and 60%, respectively) (Shantsila and Hip, 2008). Such a distinct pharmacokinetic profile was attributed to extensive first pass metabolism of apixaban in the rabbit compared with low metabolic clearance in other species.

In summary, these studies demonstrated that the metabolic pathways in the toxicological species were generally similar to those seen in humans although rabbit showed a much higher metabolic clearance than other species. Apixaban was the most prominent drug-related component in circulation of mice, rats, dogs, and humans. Apixaban clearance was demonstrated to be mediated by oxidative metabolism as well as direct renal and gastrointestinal excretion.

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REFERENCES


Footnote:

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Legends for figures:

**Figure 1.** Radiochromatograms of pooled bile, urine, and fecal samples (0-24 h) after intravenous administration of \([^{14}\text{C}]\text{apixaban}\) to bile-duct cannulated (BDC) rats. Detailed analytical procedures were described in the section of Materials and Methods.

**Figure 2.** Proposed prominent metabolic pathways of apixaban in animals and humans.

**Figure 3.** Double quantum filtered correlation spectroscopy spectrum of hydroxy apixaban, M7, with cross peaks between protons 28, 29 and 31 highlighted and labeled as A, B, and C regions.
Table 1. Mass balance results in mice, rats, rabbits, dogs, and humans after a single oral dose of $[^{14}C]$apixaban

<table>
<thead>
<tr>
<th>Species</th>
<th>Dose $^a$</th>
<th>No. of Subjects</th>
<th>Matrix</th>
<th>Sampling Time (h)</th>
<th>Recovery (% of dose)</th>
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</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>30 mg/kg</td>
<td>5</td>
<td>Urine</td>
<td>0–48</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feces</td>
<td>0–48</td>
<td>83.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>0–48</td>
<td>99.1</td>
</tr>
<tr>
<td>Rat</td>
<td>30 mg/kg</td>
<td>Intact 3</td>
<td>Urine</td>
<td>0–168</td>
<td>13.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feces</td>
<td>0–168</td>
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</tr>
<tr>
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<td>BDC</td>
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<td>Bile</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Urine</td>
<td>0–48</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feces</td>
<td>0–48</td>
<td>69.8</td>
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<td>Total</td>
<td>0–48</td>
<td>82.9</td>
</tr>
<tr>
<td>Rabbit</td>
<td>30 mg/kg</td>
<td>3</td>
<td>Urine</td>
<td>0–48</td>
<td>1.8</td>
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<tr>
<td></td>
<td></td>
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<td>Feces</td>
<td>0–48</td>
<td>54.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>0–48</td>
<td>56.1</td>
</tr>
<tr>
<td>Dog</td>
<td>5 mg/kg</td>
<td>3</td>
<td>Urine</td>
<td>0–168</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feces</td>
<td>0–168</td>
<td>73.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>0–168</td>
<td>82.5</td>
</tr>
<tr>
<td>Human</td>
<td>20 mg</td>
<td>No bile collection 6</td>
<td>Urine</td>
<td>0–292</td>
<td>25.1</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Feces</td>
<td>0–292</td>
<td>56.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>0–292</td>
<td>80.5</td>
</tr>
<tr>
<td></td>
<td>Bile</td>
<td></td>
<td>Bile</td>
<td>3–8</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Urine</td>
<td>0–216</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feces</td>
<td>0–216</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>0–216</td>
<td>77.9</td>
</tr>
</tbody>
</table>

$^a$Radiospecific activity of $[^{14}C]$apixaban used was: 5 μCi/mg for mice; 5 μCi/mg for rats (oral), 1.5 μCi/mg for rabbits, 5 μCi/mg for dogs, and 5.4 μCi/mg for humans. Human data have been presented previously (Raghavan et al., 2009) and were included here for comparison only.
Table 2. Proposed structures of [14C]apixaban metabolites and tissue occurrence

<table>
<thead>
<tr>
<th>Drug or Metabolite</th>
<th>Proposed Structure a</th>
<th>Source</th>
</tr>
</thead>
</table>
| Apixaban           | ![Proposed Structure Image](image) | Rat: Plasma, urine, feces, bile, RH<sup>df</sup>  
Mouse: Plasma, urine, feces, MH  
Rabbit: Plasma, urine, feces  
Dog: Plasma, urine, feces, DH  
Monkey: MKH  
Human: Plasma, urine, feces, bile, HH |
| M1 (O-demethyl apixaban sulfate) | ![Proposed Structure Image](image) | Rat: Plasma, urine, bile, RH  
Mouse: Urine  
Rabbit: Plasma, urine, feces  
Dog: Plasma, urine  
Monkey: MKH  
Human: Plasma, urine, feces, bile, HH |
| M2 (O-demethyl apixaban) | ![Proposed Structure Image](image) | Rat: Plasma, urine, feces, bile, RH  
Mouse: Plasma, urine, feces, MH  
Rabbit: Plasma, urine, feces  
Dog: Plasma, urine, feces, DH  
Monkey: MKH  
Human: Feces, bile, HH |
| M3<sup>b</sup> (lactam-ring opened apixaban) | ![Proposed Structure Image](image) | Rat: Bile, RH  
Mouse: MH  
Rabbit: ND<sup>c</sup>  
Dog: Urine, feces, DH  
Monkey: MKH  
Human: HH |
| M4 (hydroxy apixaban) | ![Proposed Structure Image](image) | Rat: Plasma, urine, feces, bile, RH  
Mouse: Urine, feces, MH  
Rabbit: Feces  
Dog: Urine, feces, DH  
Monkey: MKH  
Human: Feces, HH |
<table>
<thead>
<tr>
<th>Drug or Metabolite</th>
<th>Proposed Structure</th>
<th>Source</th>
</tr>
</thead>
</table>
| M5 \(^b\)        | ![Structure](image) | Rat: ND\(^c\)  
                       Mouse: MH  
                       Rabbit: ND  
                       Dog: DH  
                       Monkey: MKH  
                       Human: HH |
| M6               | ![Structure](image) | Rat: RH  
                       Mouse: MH  
                       Rabbit: ND\(^c\)  
                       Dog: ND  
                       Monkey: ND  
                       Human: ND |
| M7               | ![Structure](image) | Rat: Plasma, urine, feces, bile, RH  
                       Mouse: Plasma, urine, feces, MH  
                       Rabbit: Feces  
                       Dog: Urine, feces, DH  
                       Monkey: MKH  
                       Human: Plasma, urine, feces, bile, HH |
| M8               | ![Structure](image) | Rat: Urine, bile  
                       Mouse: ND\(^c\)  
                       Rabbit: ND  
                       Dog: Urine, feces  
                       Monkey: ND  
                       Human: ND |
| M9               | ![Structure](image) | Rat: Urine, feces, bile  
                       Mouse: urine  
                       Rabbit: ND\(^c\)  
                       Dog: ND  
                       Monkey: ND  
                       Human: ND |
| M10              | ![Structure](image) | Rat: ND\(^c\)  
                       Mouse: Plasma  
                       Rabbit: ND  
                       Dog: ND  
                       Monkey: ND |
<table>
<thead>
<tr>
<th>Drug or Metabolite</th>
<th>Proposed Structure</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>M13 (hydroxy O-demethyl apixaban)</td>
<td><img src="image" alt="Proposed Structure" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human: Plasma, feces</td>
<td></td>
</tr>
<tr>
<td>M14 (O-demethyl apixaban glucuronide)</td>
<td><img src="image" alt="Proposed Structure" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human: Feces</td>
<td></td>
</tr>
</tbody>
</table>

*aThe structures of metabolites were identified based on LC/MS analyses and mass spectral comparison with those of parent and known metabolites. *bLactam-ring opened metabolites M3 and M5 were detected in hepatocyte incubations but not in vivo of mouse, dog, or human. *cND = not detected. *dRH, MH, DH, MKH, and HH represent hepatocytes from rats, mice, dogs, monkeys, and humans. M16 as an uncharacterized oxygenated metabolite was found in rabbit urine.*
Table 3. Distribution of radioactive metabolites (percent of sample) in pooled plasma after an oral dose of [14C]apixaban to intact mice, rats, rabbits, dogs, and humans

<table>
<thead>
<tr>
<th>Metab. ID</th>
<th>Mouse (%)</th>
<th>Rat (%)</th>
<th>Rabbit (%)</th>
<th>Dog (%)</th>
<th>Human (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 h</td>
<td>4 h</td>
<td>1 h</td>
<td>4 h</td>
<td>12 h</td>
</tr>
<tr>
<td>Apixaban</td>
<td>97.3</td>
<td>75.2</td>
<td>95.5</td>
<td>94.6</td>
<td>91.4</td>
</tr>
<tr>
<td>M1</td>
<td>ND</td>
<td>ND</td>
<td>0.4</td>
<td>0.9</td>
<td>23.4</td>
</tr>
<tr>
<td>M2</td>
<td>0.6</td>
<td>3.1</td>
<td>0.6</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>M4</td>
<td>ND</td>
<td>ND</td>
<td>0.7</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>M7</td>
<td>0.4</td>
<td>2.8</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>M10</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>M13</td>
<td>0.7</td>
<td>5.8</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>M14</td>
<td>0.4</td>
<td>2.4</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Othersa</td>
<td>0.6</td>
<td>10.8</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Totalb</td>
<td>100</td>
<td>100</td>
<td>97.1</td>
<td>97.1</td>
<td>94.5</td>
</tr>
</tbody>
</table>

ND = not detected. 
*aUnidentified components. 
*Total was <100% because of unidentified minor peaks each representing <0.1%.

Human data for subjects without bile collection have been presented previously (Raghavan et al., 2009) and were included here for comparison. The samples at all other time points for rabbit, 12 h for mouse, 24 and 48 h for all species were not analyzed due to low levels of radioactivity.
Table 4. Distribution of radioactive metabolites (percent of dose) in urine and feces after an oral dose of [14C]apixaban to intact mice, rats, rabbits, dogs, and humans

<table>
<thead>
<tr>
<th>Metab. ID</th>
<th>Mouse (%)</th>
<th>Rat (%)</th>
<th>Rabbit (%)</th>
<th>Dog (%)</th>
<th>Human (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urine</td>
<td>Feces</td>
<td>Urine</td>
<td>Feces</td>
<td>Urine</td>
</tr>
<tr>
<td>Apixaban</td>
<td>13.6</td>
<td>73.2</td>
<td>12.1</td>
<td>65.9</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>39.4</td>
<td>7.2</td>
<td>58.6</td>
<td>21.5</td>
</tr>
<tr>
<td>M1</td>
<td>trace</td>
<td>ND</td>
<td>trace</td>
<td>ND</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>5.9</td>
<td>0.2</td>
<td>2.9</td>
<td>1.4</td>
</tr>
<tr>
<td>M2</td>
<td>0.5</td>
<td>5.9</td>
<td>0.2</td>
<td>2.9</td>
<td>1.4</td>
</tr>
<tr>
<td>M3</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>M4</td>
<td>0.1</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>ND</td>
</tr>
<tr>
<td>M7</td>
<td>0.1</td>
<td>3.5</td>
<td>0.2</td>
<td>2.2</td>
<td>ND</td>
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<tr>
<td>M8</td>
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<td>ND</td>
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<td>ND</td>
<td>0.2</td>
</tr>
<tr>
<td>M9</td>
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<td>ND</td>
<td>trace</td>
<td>ND</td>
<td>ND</td>
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<tr>
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<td>ND</td>
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<td>ND</td>
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</tr>
<tr>
<td>M13</td>
<td>0.5</td>
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<td>ND</td>
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<tr>
<td>Othersa</td>
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<td>0.8</td>
<td>0.2</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Totalb</td>
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<td>83.9</td>
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<td>71.8</td>
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</tr>
<tr>
<td></td>
<td>54.3</td>
<td>8.6</td>
<td>72.3</td>
<td>24.5</td>
<td>56.0</td>
</tr>
</tbody>
</table>

ND = not detected. Trace = radioactive peak observed but < 0.1%. Data are for human subjects without bile collection and for intact rats. Human data have been presented previously (Raghavan et al., 2009) and were included here for comparison. aUnidentified components. bTotal was <100% because of unidentified minor peaks each representing <0.1%. cIncluding M14 (0.22%) and M16 (0.03%).
Table 5. Distribution of radioactive metabolites (percent of sample) in incubations of [14C]apixaban with hepatocytes from mouse, rat, dog, monkey, and human

<table>
<thead>
<tr>
<th>Metabolite</th>
<th>Mouse (%)</th>
<th>Rat (%)</th>
<th>Dog (%)</th>
<th>Monkey (%)</th>
<th>Human (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 μM</td>
<td>10 μM</td>
<td>1 μM</td>
<td>10 μM</td>
<td>1 μM</td>
</tr>
<tr>
<td>Apixaban</td>
<td>91.2</td>
<td>93.3</td>
<td>88.1</td>
<td>91.1</td>
<td>86.6</td>
</tr>
<tr>
<td>M1</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>0.1</td>
<td>ND</td>
</tr>
<tr>
<td>M2</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>M3</td>
<td>0.2</td>
<td>0.2</td>
<td>ND</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>M4</td>
<td>0.1</td>
<td>0.2</td>
<td>ND</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>M5</td>
<td>1.1</td>
<td>0.8</td>
<td>ND</td>
<td>ND</td>
<td>0.5</td>
</tr>
<tr>
<td>M6</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.6</td>
<td>ND</td>
</tr>
<tr>
<td>M7</td>
<td>0.4</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Othersa</td>
<td>6.2</td>
<td>4.5</td>
<td>10.5</td>
<td>6.5</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Control incubations contained 0.3–0.7% of M7 and 2.7–4.4% of other unidentified peaks. ND = not detected.

Unidentified peaks.