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DRUG AND ALCOHOL – FORENSIC TOXICOLOGY ANNUAL REPORT 2016

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16. Abstract

The Bioaeronautical Sciences Research Laboratory (BSRL) is a branch of the Aerospace Medical Research Division that includes three teams focused on improving aviation safety through accident investigation. The Autopsy Program Team is an operational team that collects, manages, and maintains all autopsy records from the investigation of fatal aircraft accidents in the United States and supports the aeromedical review of these accidents. The Biochemistry and Forensic Toxicology teams conduct research on accident fatalities and serve as the primary national site for toxicology testing of federal agencies, including the FAA and the National Transportation Safety Board (NTSB).

In 2016, the BSRL received 307 cases from accidents in various modes of transportation including aviation, highway, marine, and rail. The laboratory received biological specimens from 22 incidents in which the pilot, driver, or primary operator was nonfatal. Toxicological analysis was performed on 296 cases, 19 of which were analyzed only for Carboxyhemoglobin. Of the 277 cases that were analyzed for drugs, 122 were negative and 155 were positive for at least one drug.

This report contains widely requested data on the toxicological findings of the cases handled by the BSRL. This report includes comparisons of data over a five-year period. The aerospace community, including FAA leadership, NTSB personnel, aerospace researchers, forensic toxicologists, and the public will use the findings and trends of this report to assess transportation safety.

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INTRODUCTION

The Civil Aerospace Medical Institute (CAMI) is the medical certification, education, research, and occupational medicine wing of the Office of Aerospace Medicine (AAM) under the guidance of the Federal Aviation Administration (FAA) Office of Aviation Safety (AVS). CAMI is located at the Mike Monroney Aeronautical Center (MMAC), in Oklahoma City, OK.

The Bioaeronautical Sciences Research Laboratory (BSRL, AAM-610) is a branch of the Aerospace Medical Research Division (AAM-600). The mission of AAM-600 is "to develop new and innovative ways to support FAA regulatory and advisory missions to improve the safety of humans in civilian aerospace operations." As such, its goal is to "Continuously maintain the Absorptive Capacity for applying Science, Medicine, Bioengineering, and Technology to unrelentingly enhance human safety."

In 2016, AAM-600 was reorganized and the BSRL was divided into two sections, Forensic Sciences (AAM-611) and Biomedical Sciences (AAM-612). Forensic Sciences is composed of the Forensic Toxicology Research Team and the Biochemistry Research Team. The Functional Genomics and Knowledge Management Research Teams, along with the Autopsy Program Team, make up the Biomedical Sciences Section. The Autopsy Program Team is an operational team that collects, manages, and maintains all autopsy records from the investigation of fatal aircraft accidents in the United States and supports the aeromedical review of these accidents. The Biochemistry and Forensic Toxicology teams conduct research on accident fatalities and serve as the primary national site for toxicology testing of federal agencies, including the FAA and the National Transportation Safety Board (NTSB). The AAM-610 organizational chart is presented in Figure 1.

The laboratory is certified in accordance with the International Organization for Standardization (ISO) standard 9001:2008 (July 2015). The laboratory is also accredited by the American Board of Forensic Toxicology (ABFT). The mission of the ABFT is to establish standards for the practices of laboratories involved in postmortem toxicology and/or human performance testing. The accreditation process includes an on-site inspection every two years and a thorough review of documentation and procedures in the year between the on-site inspections. Accreditation is also contingent upon the successful performance of proficiency tests provided by the College of American Pathology. ABFT has established a certification program for scientists that are engaged in the practice of forensic toxicology and successfully pass an examination. In 2016, three BSRL employees held certifications as a Fellow of ABFT (F-ABFT) and one employee as a Diplomat of ABFT (D-ABFT).

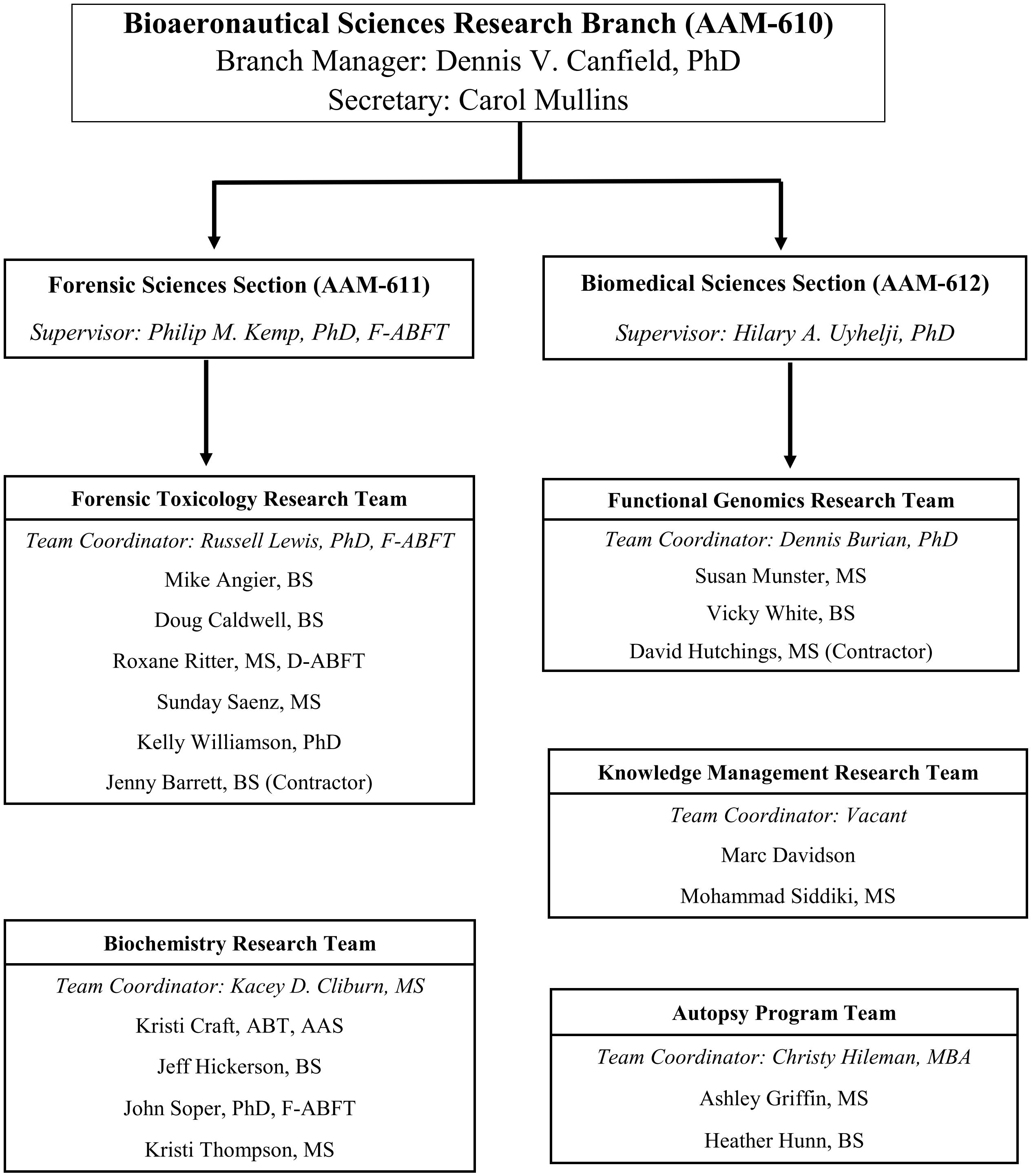


Figure 1. AAM-610 Organizational Chart, as of December 2016

Autopsy Program Team

The FAA has statutory authority and a congressional mandate to conduct accident prevention and crash injury research by collecting relevant data in the interest of protecting public safety. The Autopsy Program Team at the FAA exists to assist accident investigation with the medical portion of the investigation process. The autopsy program team is involved in all U.S. registered civilian aviation accidents where a fatality occurs. The team works with FAA and NTSB investigators as well as local medicolegal jurisdictions to obtain autopsy and toxicological specimens for each fatal pilot, co-pilot, pilot rated passenger, or other passenger that may have had control of the aircraft at the time of the accident. Autopsy and toxicology are an important part of the accident investigation in that they aid investigators in determining what was going on with the airman or occupants at the time of the accident. Results from the autopsy report and toxicology report help to rule out or discover any impairments or incapacitations. The reports also assist in identifying any existing medical conditions that may or may not have been previously disclosed to the FAA's Aviation Medical Examiner (AME).

For the majority of 2016, the Autopsy team consisted of two full time autopsy records administrators whose background is in health information management. In October of 2016, the team added a third full time employee. The Autopsy team has a database, the Medical Analysis and Tracking (MANTRA) Registry, to store all of the information obtained during their role in accident investigation. Others within the FAA use the data contained in the database to conduct research on fatal accidents. The research is intended to improve aviation safety, health, security, and survivability in the aviation community. The research conducted at CAMI brings understanding to aeromedical factors in aviation accidents and studies performance decrements resulting from disease processes to determine their effects on aviation safety. One of the focuses of the research performed at CAMI is to evaluate factors that influence human performance in aviation and communicate that to the aviation community.

Biochemistry Research Team

The Biochemistry Team started 2016 with six members: two Research Toxicologists, two Research Chemists, and two laboratory technicians. After a reorganization in September 2016, the team is now comprised of five staff members: one Research Toxicologist, two Research Chemists, and two Laboratory Technicians. Their functions include but are not limited to (1) creation of the initial case folders, (2) accessioning, (3) analytical batch review, (4) completion of the case reports, and (5) research.

After an aviation accident, or other transportation related accident, an autopsy is performed by the local Medical Examiner or Coroner. Upon request by the NTSB, biological specimens from an accident victim are shipped in a TOX-BOX to the laboratory (1). Toxicological testing is provided to several agencies, besides the FAA and NTSB, including the Royal Canadian Air Force, U.S. Coast Guard, and various other U.S. and foreign agencies.

Once a TOX-BOX is received, a case is created and given a unique case number. The contents are videotaped and cataloged as to the specimen types and their weight, noting any distinguishing characteristics, such as putrefaction, charring, debris, limited in volume, etc. Batches are prepared for toxicological testing by transferring aliquots of the biological specimens into test tubes. These batches are created for the analysis of carboxyhemoglobin, alcohols/volatiles, glucose, drugs of abuse, and therapeutic drugs. The type of tests requested is dependent upon the specimen type received and/or whether the specimens are suitable for use. Pilot and co-pilot victims receive full toxicological testing. Passenger victims are not tested unless either the investigator deems toxicological testing is necessary, or there was a fire at the crash site, in which testing for carbon monoxide exposure (carboxyhemoglobin) would be performed. The TOX-BOX is then cleaned, a new kit inserted, and the box is shipped back to the office from which it originated.

Once the initial testing batch has been analyzed, the results are reviewed and additional batches may be requested/created depending on the results. The case files are monitored for completion of all required analyses and the final case reports are then generated for distribution to FAA and NTSB personnel.

In addition to the processing of case specimens from aviation or surface accidents, the Biochemistry Research Team also conducts research. The Team's research interests include epidemiology studies, prevalence studies of various drug classes, and method development for the analysis of cannabinoids in postmortem samples. This research helps to identify trends in drug and alcohol use in the fatal pilot population.

Forensic Toxicology Research Team

The Forensic Toxicology Research Team consists of seven members: six Research Chemists and one Biological Science Laboratory Technologist (contractor) who together encompass more than 106 years of experience. Two team members hold Ph.D., two M.S., and three B.S. degrees. Two team members are board certified with the ABFT. The Forensic Toxicology Research Team performs toxicological analysis on biological specimens obtained from transportation accidents. The NTSB, FAA, and local investigators use information gathered from these activities to aid in the determination of a cause of an aviation or other transportation accident.

The Forensic Toxicology Research Team initially screens case specimens for illicit, over-the-counter (OTC), and prescription drugs using immunoassay, gas chromatography-mass spectrometry (GC/MS), liquid chromatography/ mass spectrometry (LC/MS), and liquid chromatography/ultraviolet/visible/ fluorescence (LC/UV/VIS/FL). Presumptive positives from this screening are assigned for confirmation and quantification by the Forensic Toxicology team using GC/MS and liquid chromatography/tandem mass spectrometry (LC/MS/MS). Additionally, case specimens are analyzed for ethanol/volatiles, combustion gases, and glucose/HbA1c, if suitable specimens exist. Ethanol and other volatiles are analyzed by headspace gas chromatography (GC-HDSP). Ultraviolet/Visible Spectrophotometry (UV/VIS) and colorimetric tests are used to analyze for carbon monoxide (carboxyhemoglobin) and cyanide.

Sample preparation and handling is required prior to analytical instrument analysis. Biological tissues must be homogenized and then handled alongside the fluid samples. Typical sample preparations include, but are not limited to, solid phase extraction, liquid-liquid extraction, or modified “crash and shoot” methods. Chemists prepare and analyze positive and negative controls for each analysis. For drug confirmation/quantification, calibration curves and controls are prepared for each analysis.

In addition to the analysis of case specimens from aviation or surface accidents, the Forensic Toxicology Research Team also conducts research. The Team’s research interests include method development and validation for current and emerging drugs, postmortem drug distribution and redistribution, and postmortem ethanol formation. This innovative research, in combination with the day-to-day forensic toxicology casework, aids in the development of accident prevention strategies and overall safety improvement to the flying public.

Objectives

The objectives of this report are

(1) to provide descriptive characteristics of all cases received by the laboratory for processing and toxicological analyses;
(2) to evaluate aviation accidents in regards to the type of accident, location of the accident, occupant role, and medical certification status;
(3) to examine current trends in drug and alcohol usage in the cases received by the laboratory;
(4) to contribute to discussions about policy changes regarding drug use; and
(5) to educate the pilot population about the dangers of drug use in aviation.

METHODS

Since 1990, a database (ToxFlo™, DiscoverSoft Development, LLC) has been maintained at the Civil Aerospace Medical Institute (CAMI) that includes information relating to the biological specimens received by the CAMI Biochemistry Research Team and the results of the forensic toxicology analysis performed by the CAMI Forensic Toxicology Research Team. Information obtained during the accident investigation is sent to CAMI and posted in ToxFlo™. The information may include, but is not limited to, the victim's name, date of birth, social security number, and gender. The accident information includes the accident date and location and, if it is an aviation accident, information about the type of operation or aircraft registry. This information may also be obtained from the CAMI Autopsy Program Team's spell-out (MANTRA) registry. The pilot's certificate number is obtained from the FAA's Multi-System Access Tool – Airman (MSAT-A). The pilot's medical history, including pilot class, is obtained from the the FAA's Medical Support System-Document Imaging Workflow System (MSS-DIWS).

The ToxFlo™ database was searched to establish the number of cases received during the calendar year 2016. At the time of data collection, all 2016 cases were complete and reports had been issued. Accidents that occurred in 2015, but for which biological specimens were not received by the laboratory until 2016, were included as a part of the data for 2016. The MANTRA database was searched to obtain corresponding information about the selected 2016 aviation accidents. The data collected for aviation cases received by the laboratory included age, fatal or nonfatal status, accident date and location, type of flight, occupant role (pilot, co-pilot, passenger, etc.), and pilot's medical certificate status. The data collected for non-aviation cases received by the laboratory included, age, fatal or nonfatal status, accident date and location, and mode of transportation. Results from the toxicological analyses were collected for all cases, regardless of mode of transportation or fatal status. The toxicology results were evaluated based on the types of tests that were performed and the number of cases that were positive for drugs, alcohol, carboxyhemoglobin, cyanide, and glucose.

In this report, comparisons of various categories was performed for a five-year period from 2012-2016. The laboratory assessed the total number of cases received, the number of nonfatal cases received, the number of aviation accidents, the number of non-aviation accidents, the number of female pilots received, the number of accidents involving a light-sport aircraft, and the percent of positive findings from toxicology analysis.

RESULTS

Number of Cases Received

The laboratory received 307 cases from aviation, highway, rail, and marine accidents (Figure 1). There were 22 cases received from nonfatal accidents (Table 1).

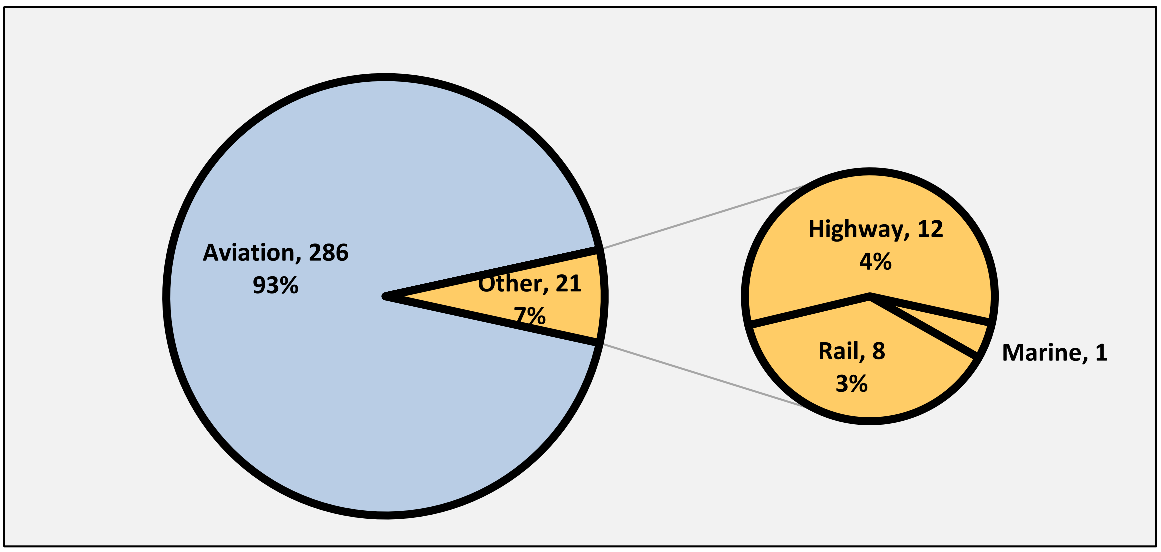


Figure 2. Number of Cases Received by BSRL by Mode of Transportation

Table 1. Nonfatal Cases Received by Mode of Transportation

Mode of Transportation	Number of Cases Received
Aviation	13
Highway	6
Marine	1
Rail	2
Total	**22**

Aviation

Type of Flight

The laboratory received 286 aviation cases from a total of 221 accidents (Table 2). Of these 221 accidents, the NTSB investigated 207 accidents operating under various parts of Title 14 of the Code of Federal Regulations (14 CFR) and 4 accidents operating under Public Aircraft and Foreign Authority (2,3). The laboratory received 5 accidents that were not investigated by the NTSB, but involved an FAA investigation. The laboratory received 5 cases at the request of other government agencies that did not involve any FAA or NTSB investigation.

Table 2. Type of Flight

Type of Flight (NTSB & FAA Investigations)	Number of Accidents
General Aviation (14 CFR Part 91)	185
Agricultural (14 CFR Part 137)	12
Air Taxi and Commercial (14 CFR Part 135)	10
Public Aircraft	3
Foreign Authority – Bahamas	1
Total	**211**

Type of Flight (FAA Investigations)	Number of Accidents
Ultralight (14 CFR Part 103)	3
Unregistered Hang Glider	1
Parachute	1
Total	**5**

Type of Flight (Other Government Requests)	Number of Accidents
Foreign - Royal Canadian Air Force	4
US Military	1
Total	**5**

Location

Cases were received from 221 aviation accidents in the United States, Canada, and the Bahamas. Figure 3 displays the locations of accidents occurring in the United States (N=216).

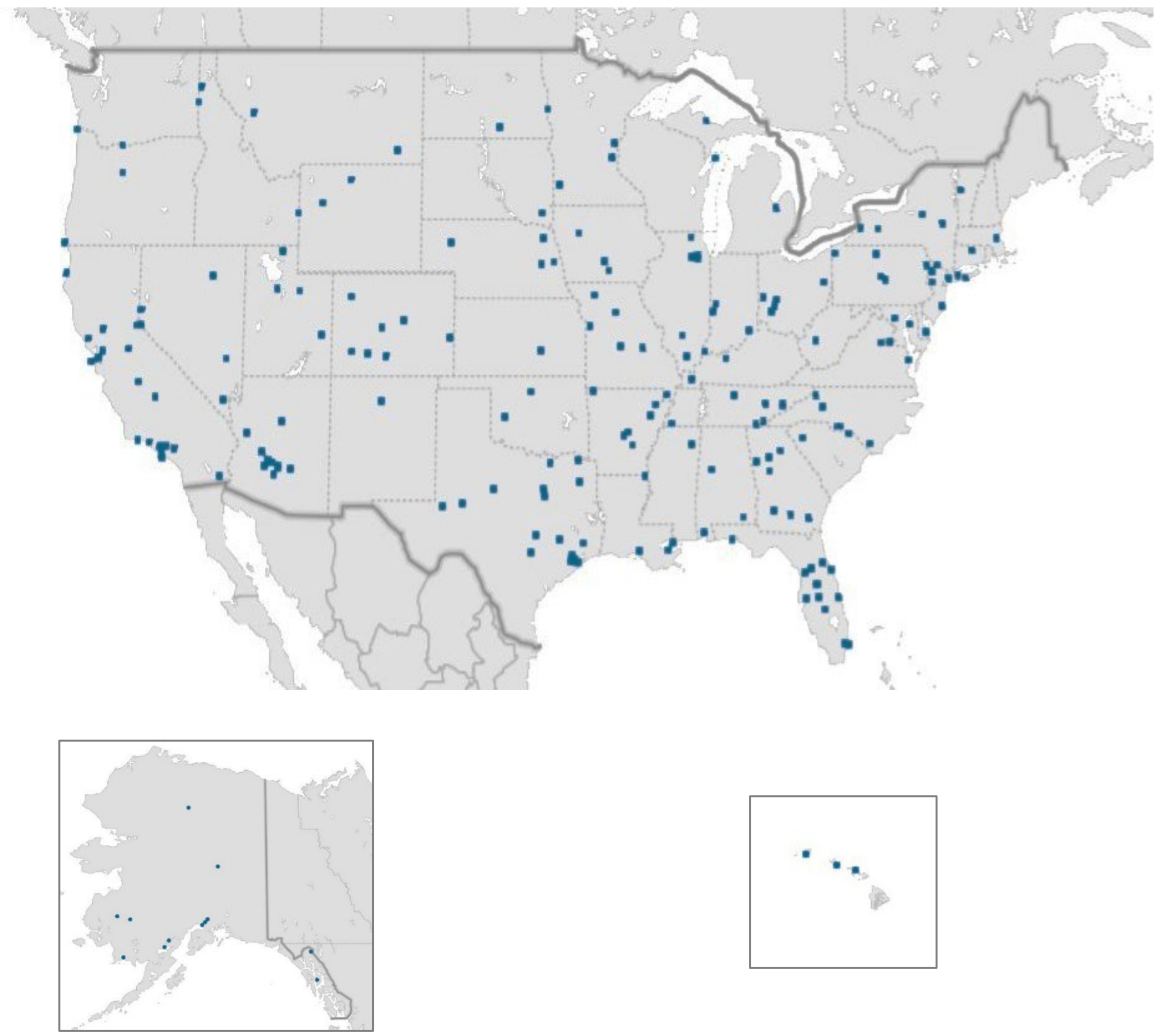


Figure 3. U.S. Aviation Accidents Classified by Location

Month, Day of the Week

Aviation accidents (N=221) occurred in every month and on every day of the week. Accidents happened the most during the month of August and on a Friday. Eight accidents occurred in December 2015, but the cases were not received or processed by the laboratory until 2016. These are included in the total for December (*).

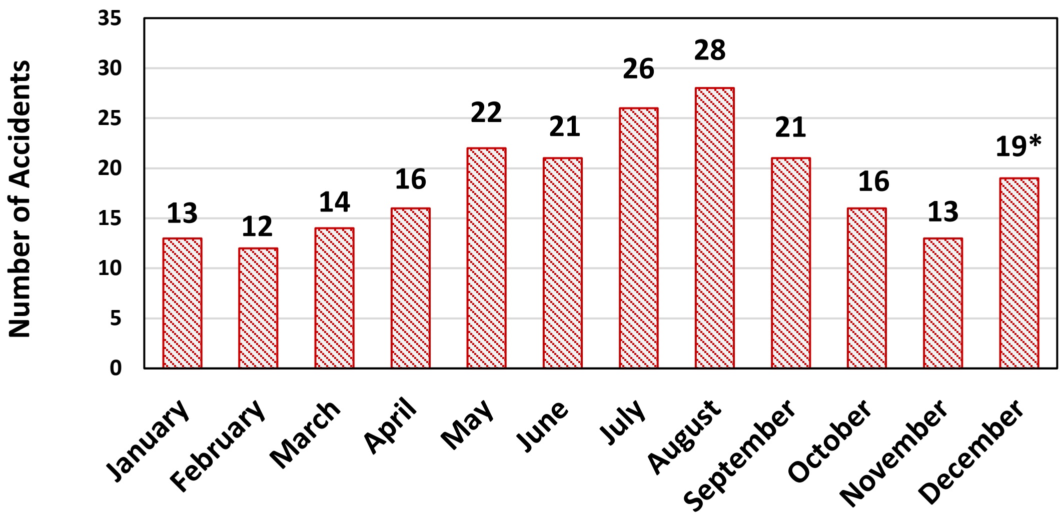


Figure 4. All Aviation Accidents Classified by Month

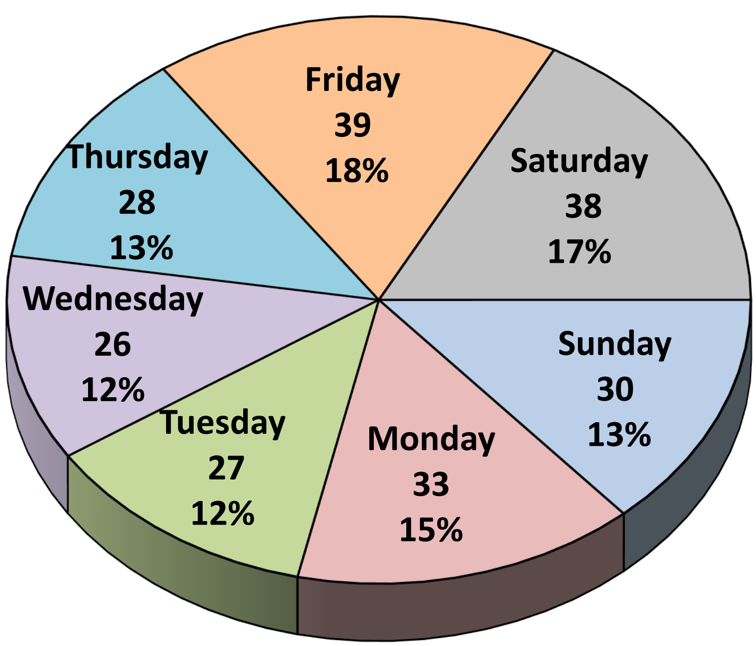
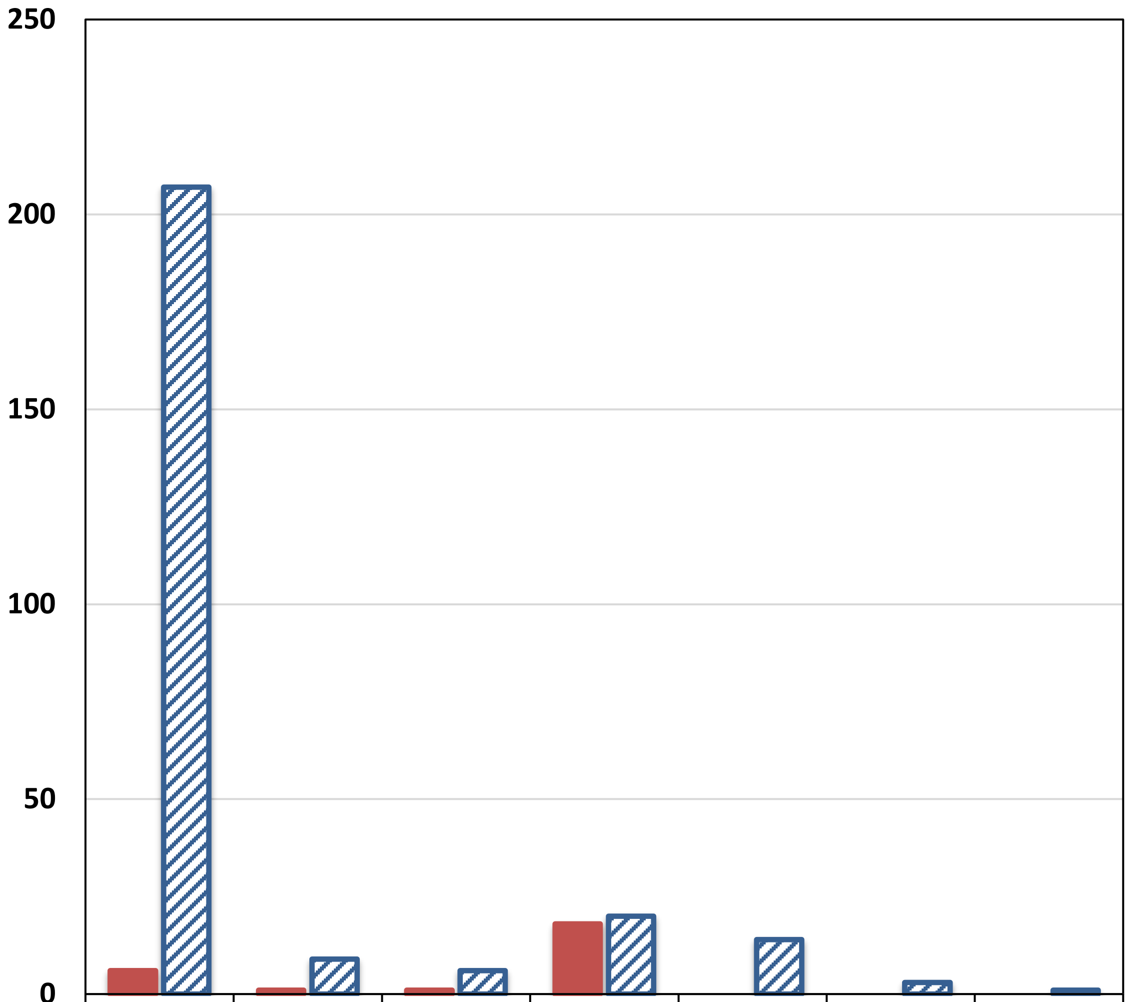


Figure 5. All Aviation Accidents Classified by Day of the Week

Occupant Role

Cases were received from various occupants in the aviation accident. The occupants (N=286) received in 2016 were classified by the laboratory as pilot, flight, co-pilot, passenger, pilot-rated passenger (PAX), crewmember, or parachutist. Pilot-rated PAX refers to individuals that have a medical certificate to fly, but were in the aircraft as a passenger. Ninety-one percent of the occupants received were male.



	Pilot	Flight Instructor	Co-pilot	Passenger	Pilot Rated PAX	Crew Member	Parachutist
Female	6	1	1	18	0	0	0
Male	207	9	6	20	14	3	1

Figure 6. Occupant Role by Gender

Age of Occupants

The laboratory received 286 cases from 221 aviation accidents. Two hundred thirty cases were classified as pilot, co-pilot, or flight instructor, while 56 cases were classified as passengers, pilot-rated PAX, crew member, or parachutist. The average age for all aviation cases received is 53.4.

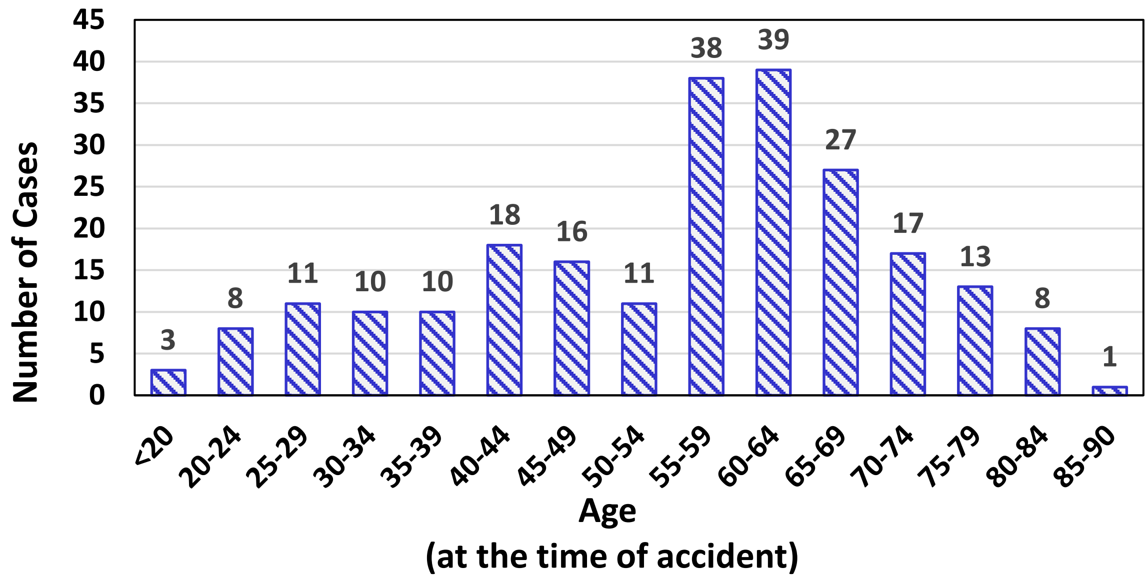


Figure 7. Pilots, Co-pilots, and Flight Instructors Classified by Age (years)

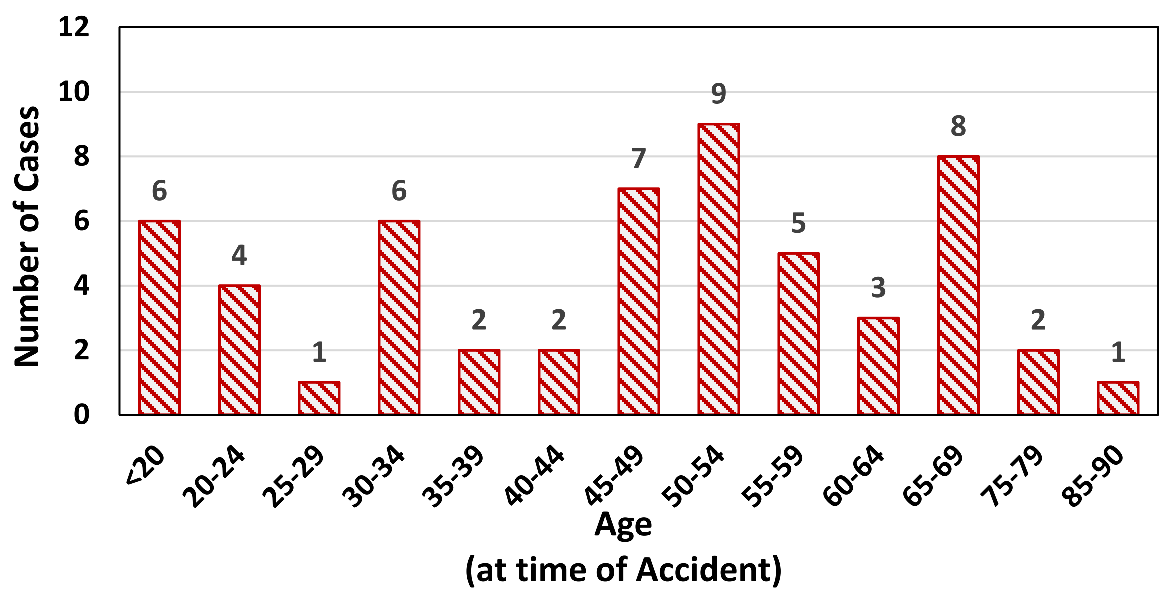


Figure 8. Non-pilots Classified by Age (years)

Medical Certification

The FAA has standards and procedures for a pilot to obtain a medical certificate in order to exercise the privileges of an airline transport, a commercial, or a private pilot (2). The three classes for airmen medical certificates are First-Class Medical Certificates, Second-Class Medical Certificates, and Third-Class Medical Certificates.

The First-Class Medical Certificate is required for Airline Transport Pilots. Airline Transport Pilots are at least 23 years of age and require more flight training than other certificate types. They fly for compensation or hire.

The Second-Class Medical Certificate is required for commercial pilots, flight engineers, flight navigators, and air traffic control tower specialists. Commercial pilots may operate an aircraft that is carrying passengers or property for compensation or hire.

The Third-Class Medical Certificate is required for private pilots, recreational pilots, student pilots, and certified flight instructors. Private pilots must be at least 17 years of age. They cannot act as a pilot in command of an aircraft that is carrying passengers or property for compensation or hire. Recreational pilots must also be at least 17 years of age and are not to carry more than one passenger. Student pilots must be at least 16 years of age. They are not to act as a pilot of an aircraft carrying any passengers or carrying property for compensation or hire.

Sport pilots are not required to hold a valid airman medical certificate if they have a current valid U.S. driver's license. Any restrictions on their driver's license applies to flying as well.

In 2016, the laboratory received 182 cases in which a medical certificate was required for the pilot to operate the aircraft. The laboratory received 34 cases in which a medical certificate was not required for the pilot to operate the aircraft. The laboratory also received 18 cases, pilot-rated PAX, in which the occupant was a passenger but held a valid or had an out of date medical certificate.

Age

Medical data from the most recent medical examinations are abstracted from the FAA's Medical Support System to produce summary statistics for the Aerospace Medical Certification Statistical Handbook (4). The following is a comparison of age for the 230 pilots, co-pilots, and flight instructors received by the laboratory with the active airmen in 2016. In 2016, there were 560,152 medically certified airmen age 16 and older.

Table 3. Age Group of BSRL Cases and Active Airmen

Age as of Accident or Exam Number (Percent)		
Age Range	**BSRL Cases - Accident**	**Active Airmen - Exam**
<20	3 (1.30)	16,255 (2.90)
20-24	8 (3.48)	56,713 (10.12)
25-29	11 (4.78)	63,679 (11.37)
30-34	10 (4.35)	56,448 (10.08)
35-39	10 (4.35)	51,467 (9.19)
40-44	18 (7.82)	47,834 (8.54)
45-49	16 (6.96)	48,340 (8.63)
50-54	11 (4.78)	54,660 (9.76)
55-59	38 (16.52)	56,460 (10.08)
60-64	39 (16.96)	46,838 (8.36)
65+	66 (28.70)	61,458 (10.97)
Total	**230**	**560,152**

Table 4. Summary Statistics of Age

	Number	Age Mean	Age Median	Age Standard Deviation
BSRL Cases	230	55.1	58	16.1
Active Airmen	560,152	44.3	43.6	15.9

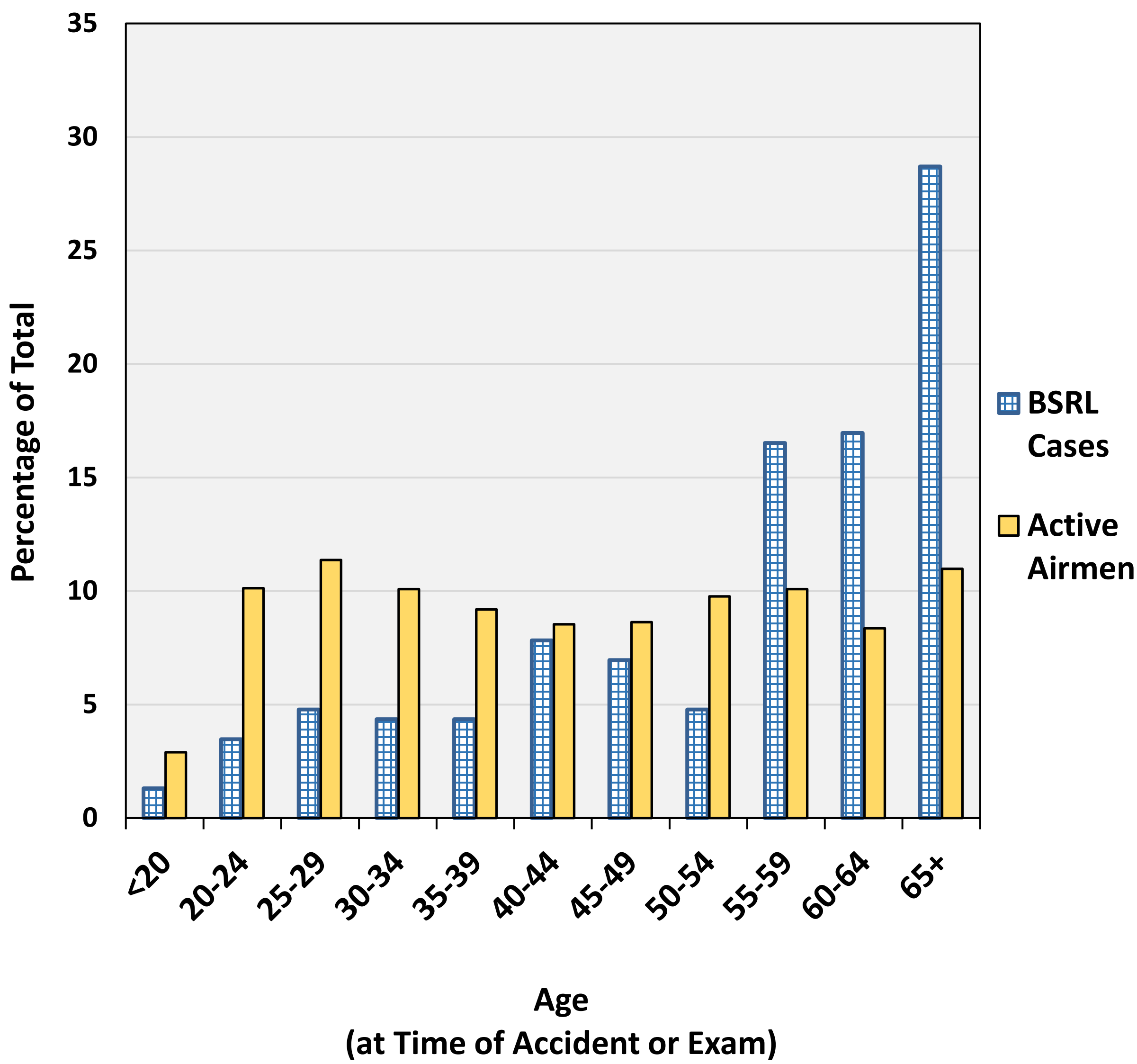


Figure 9. Comparison of Age (years) between Cases and Active Airmen

Accidents Requiring Valid Medical Certificate

Of the 230 pilots, co-pilots, and flight instructors received by the laboratory, 182 were involved in a fatal aviation accident in the United States in which a medical certificate was necessary for operating the aircraft. Figure 10 shows that 14 cases received did not have a valid medical certificate when the accident occurred. The majority of the cases that held a current medical certificate were Third Class pilots, as seen in Figure 11.

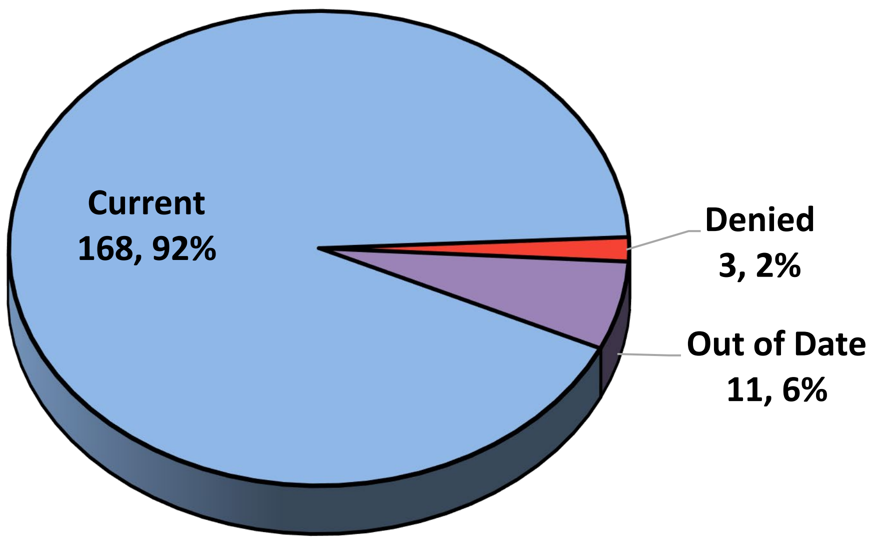


Figure 10. Medical Certificate Status for Accidents Requiring a Valid Certificate

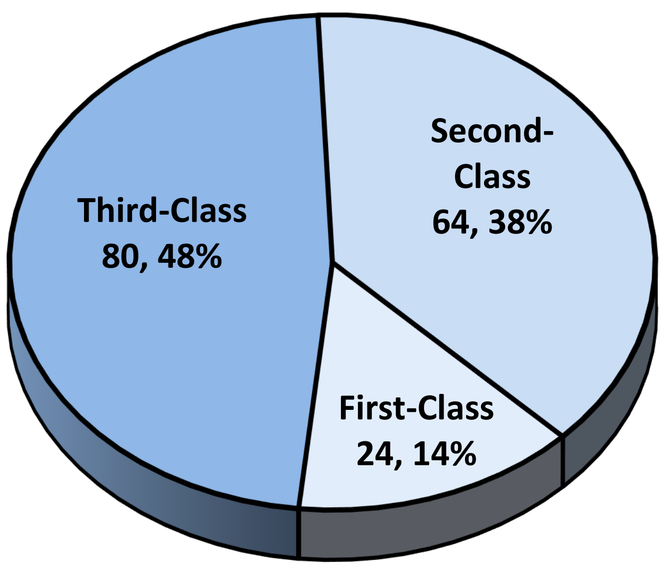


Figure 11. Pilots with Current Medical Certificate Classified by Pilot Class

Accidents Not Requiring Valid Medical Certificate

Of the 230 pilots, co-pilots, and flight instructors received by the laboratory, 34 were involved in fatal aviation accidents in the United States in which a medical certificate was not required for operating the aircraft. Figure 12 shows that the majority of the cases in these accidents had an out of date medical certificate.

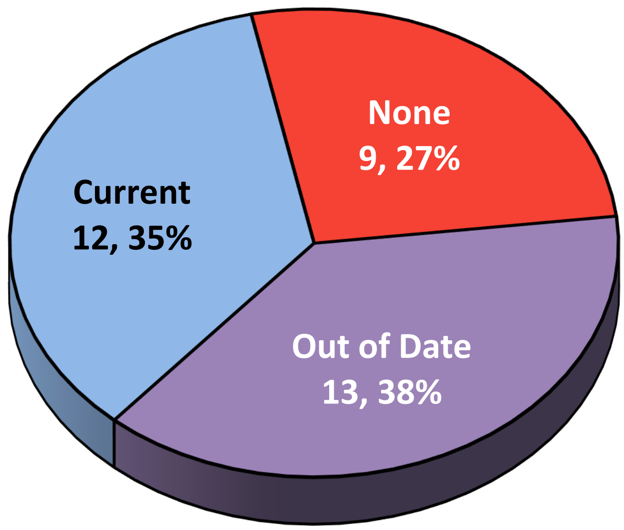


Figure 12. Medical Certificate Status for Accidents Not Requiring a Valid Certificate

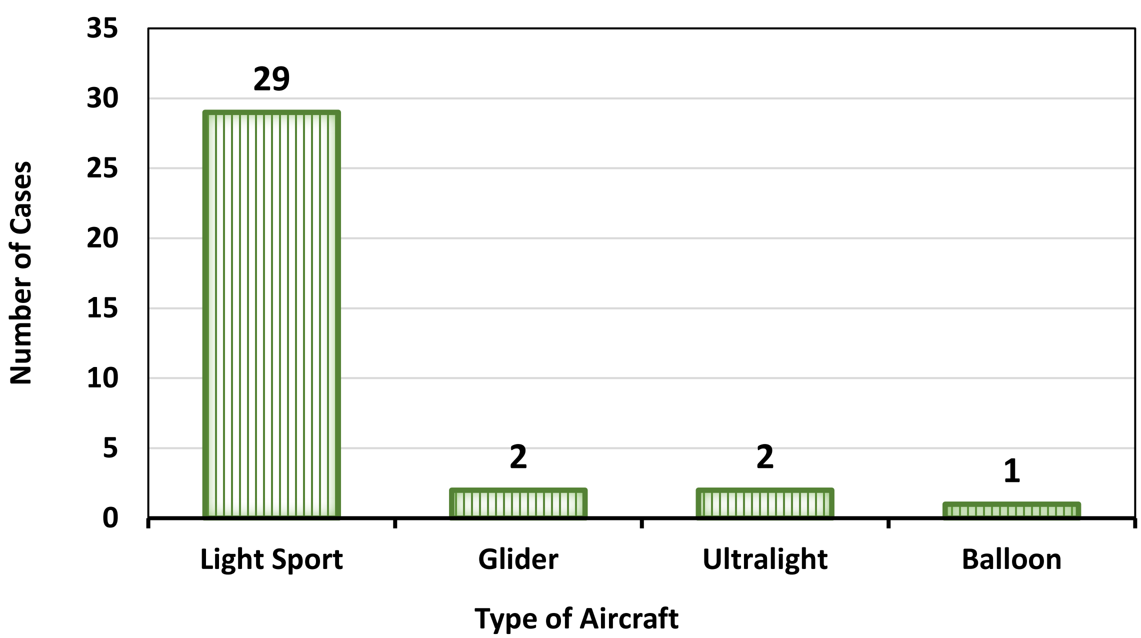


Figure 13. Type of Aircraft in Accidents Not Requiring a Medical Certificate

Passengers Medical Certificate Status

Of the 52 fatal passengers received by the laboratory, 14 held a current medical certificate and 4 had an expired/denied medical certificate. Figure 15 shows that the 14 pilot-rated passengers were either Second Class or Third Class pilots.

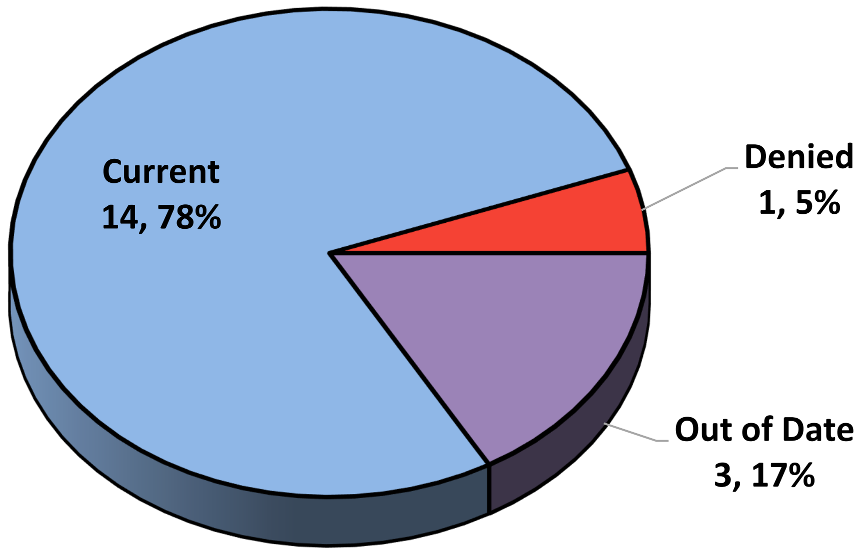


Figure 14. Medical Certificate Status for Passengers

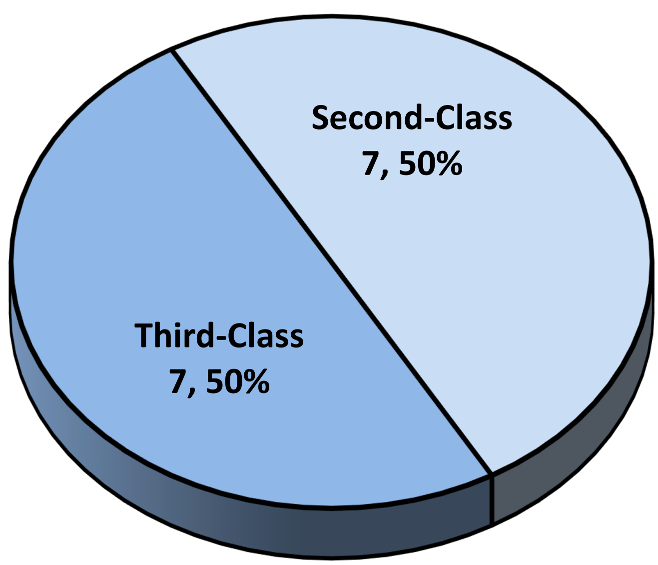


Figure 15. Pilot-Rated Passengers Classified by Pilot Class

Other Modes of Transportation

In 1967, the NTSB was established by Congress as an independent investigative agency of civilian aviation accidents and major accidents in other modes of transportation, such as highway, railroad, marine, and pipeline. The Safety Board determines the probable cause of each accident and promotes safety recommendations aimed at preventing future accidents. The laboratory assists in the NTSB investigations by providing toxicological support for non-aviation accidents (5). The non-aviation accidents that are sent in for toxicological analysis are determined by the NTSB.

In 2016, the laboratory received biological specimens from 21 non-aviation accidents investigated by the NTSB. The month of June had the most accidents investigated by NTSB and biological specimens sent to the laboratory for toxicology analysis (Figure 16). The non-aviation accidents were received from 12 states, with the most accidents occurring in Texas (Figure 17).

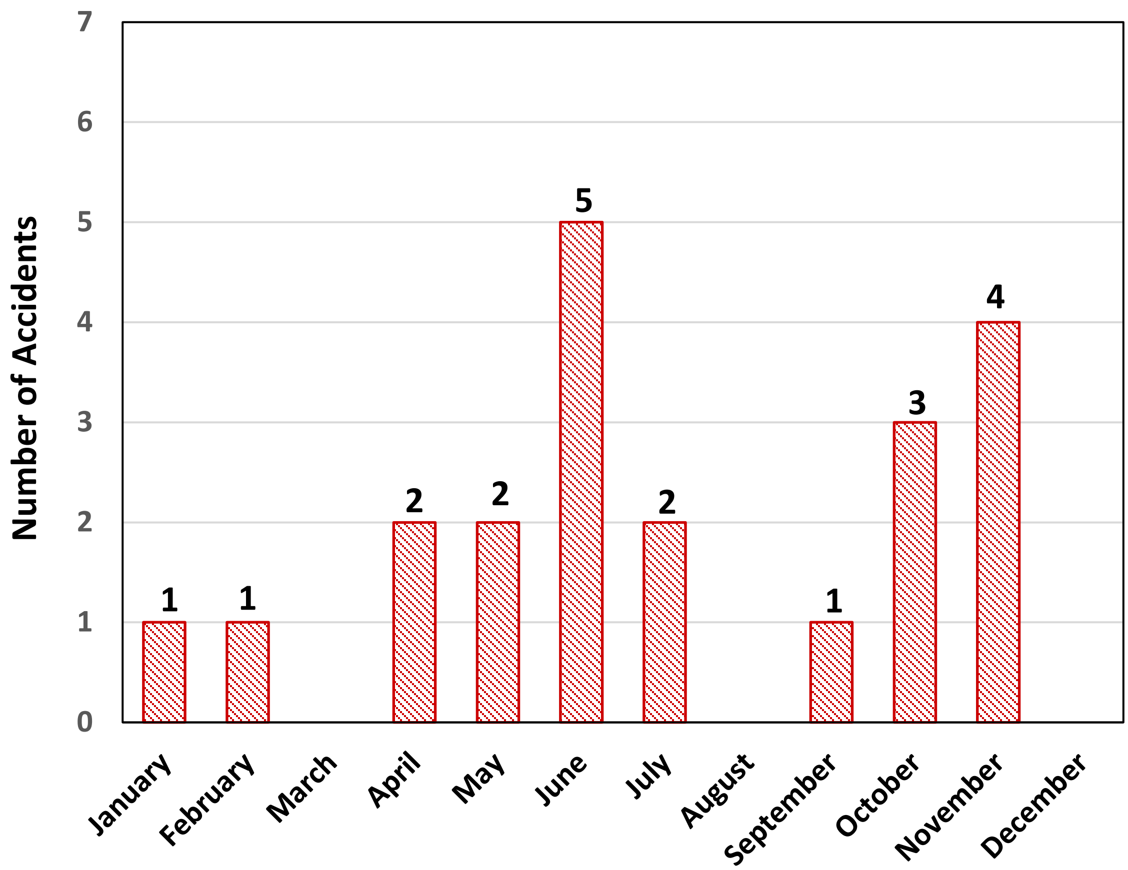


Figure 16. Non-Aviation Accidents Classified by Month

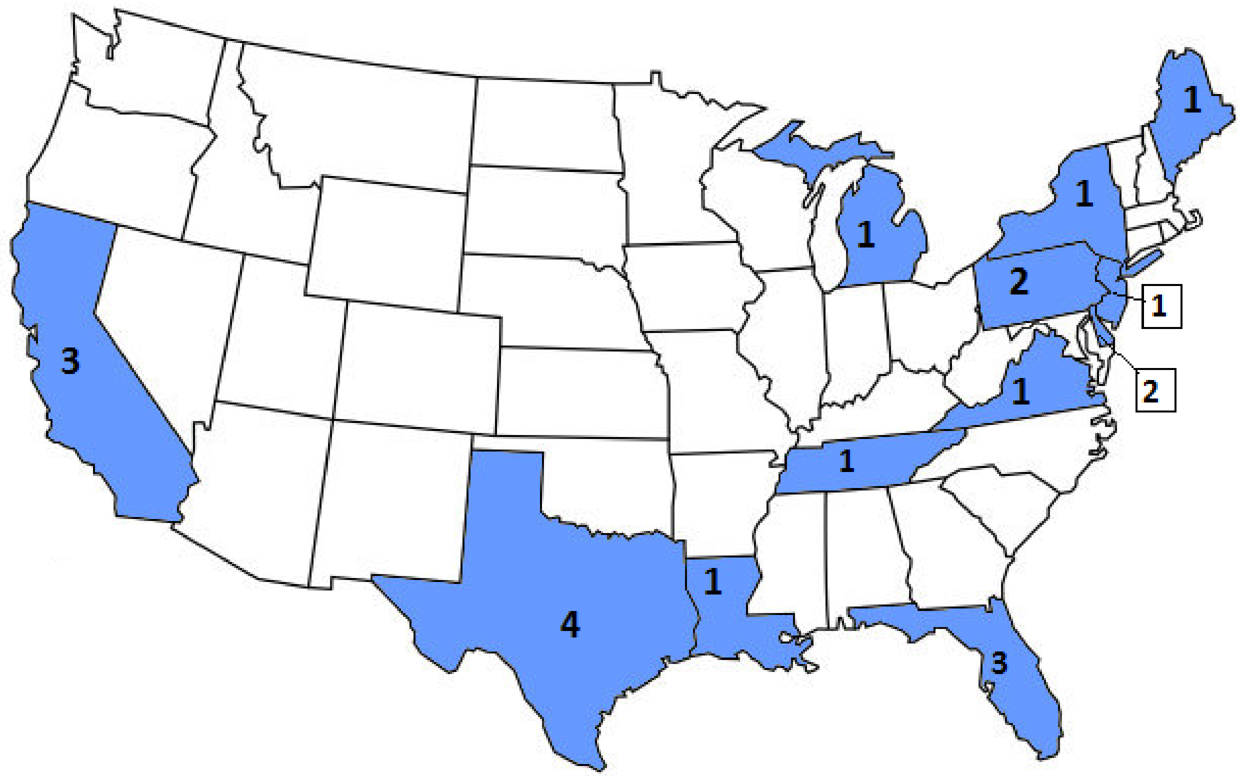


Figure 17. Non-Aviation Accidents Classified by U.S. Location

Toxicology

In 2016, toxicological analyses were performed on 296 (96%) of the cases the laboratory received. Eleven cases received by the laboratory had no analyses performed due to lack of sufficient specimens, condition of specimens, or a request from the investigator in charge of the case that no toxicology testing be performed. The results from the toxicology tests performed are summarized in this section and includes all modes of transportation, as well as fatal and nonfatal cases.

Carboxyhemoglobin: The laboratory tested 186 (61%) cases for the presence of carboxyhemoglobin. This test is performed on a blood sample, thus if there was no blood received with the case, the test was not performed. The laboratory reports carboxyhemoglobin positive result greater than or equal to 10%. In 2016, 13 cases tested positive for carboxyhemoglobin.

Cyanide: A test is performed for cyanide on any case that is positive for carboxyhemoglobin. The laboratory performed a cyanide analysis on 13 cases in 2016.

Glucose: The laboratory tested 175 (57%) cases for the presence of glucose. This test is performed on urine and/or vitreous humor samples. The laboratory does not report glucose results that are less than 100 mg/dL in urine or 125 mg/dL in vitreous humor. In 2016, glucose-positive results were reported in 10 cases.

Hemoglobin A1c: A test is performed for hemoglobin A1c on any case that has a glucose result greater than 100 mg/dL in urine or 125 mg/dL in vitreous humor or by special request from the NTSB/FAA Investigator. The test is performed on blood and the laboratory tested 11 cases for hemoglobin A1c in 2016.

Volatiles: The laboratory tested 276 (90%) cases for the presence of volatile substances, including ethanol, methanol, isopropanol, and acetone. This test may be performed on vitreous humor, urine, blood, bile or a tissue sample, such as liver, lung, kidney, muscle, brain, heart. An ethanol result greater than or equal to 10 mg/dL is reported by the laboratory. In 2016, 7 cases had a blood sample with an ethanol concentration greater than 40 mg/dL (0.04 percent = 40 mg/dL). According to Title 14 CFR Section 91.17, "No person may act or attempt to act as a crewmember of a civil aircraft… while having .04 percent by weight or more alcohol in the blood."

Drugs: The laboratory tested 277 (90%) cases for the presence of illicit, prescription, and over-the-counter medications. The test may be performed on urine, blood, or tissue samples. In 2016, 155 (50%) cases were positive for one or more drugs while none were detected in 122 (40%) cases.

Carboxyhemoglobin

Carbon monoxide (CO) is a byproduct of incomplete combustion. It is a toxic gas which can occur as a result of a fire. Carbon monoxide binds with hemoglobin forming carboxyhemoglobin, which interferes with the transportation of oxygen in the body. Carboxyhemoglobin levels can cause various symptoms ranging from headache to convulsions (6).

Table 5. Carboxyhemoglobin Levels and Symptoms

Percentage	Symptoms
10-20%	Headache, flushed skin, and/or shortness of breath with moderate exercise
20-30 %	Throbbing headache, memory and/or judgement impairment, confusion, irritability, emotional instability, and/or rapid fatigue
30-40%	Severe headache, visual disturbances, nausea, vomiting, dizziness, and confusion
40-50%	Hallucinations, abnormally rapid breathing, and/or ataxia
>50%	Lethal with symptoms of syncope, coma, tachycardia, incontinence, convulsions, discoloration of skin, loss of reflexes, and/or respiratory paralysis

Cyanide

Cyanide gas (CN^-) can be produced by the burning of carbon and nitrogen containing materials (6). Hydrogen cyanide (HCN) is the fastest acting form of the gas. CN^- binds to an enzyme in the electron transport system, interrupting the electron transport cycle which is the central pathway for energy generation necessary for life. Inhalation of a large amount of HCN is fatal in less than one minute (7). Symptoms from oral or dermal exposure depend on variables such as the extent, rate, and site of absorption of the cyanide. The onset of symptoms is slower with this type of exposure. Headache, dizziness, and rapid breathing occur immediately after exposure. The symptoms increase to slowed respiration, gasping breaths, erratic cardiac rhythms, hypotension, coma, seizures and death (6).

Table 6. Carboxyhemoglobin and Cyanide Results

Case	Specimen	Carboxyhemoglobin, %	Cyanide, µg/mL
1	Blood (Cavity)	19	0
2	Blood (Subclavian)	40	0
3	Blood (Femoral)	20	0
4	Blood (Heart)	13	0
5	Blood (Heart)	15	0.40
6	Blood (Cardiac)	10	0
7	Blood	22	0
8	Blood	34	1.96
9	Blood (Heart)	23	0
10	Blood	48	0
11	Blood (Femoral)	23	0
12	Blood (Peripheral)	16	0
13	Blood	38	0

Glucose and Hemoglobin A1c

Blood glucose concentrations can be elevated in people with diabetes mellitus. The specimen of choice for postmortem glucose concentrations is vitreous humor or urine, since postmortem blood glucose concentrations have been shown to drop rapidly after death. Vitreous humor is the clear gel that occupies the space between the lens and retina of the eyeball and displays good stability for many drugs and compounds. Normal vitreous humor concentrations for glucose is less than 200 mg/dL. Glycolated hemoglobin (HbA1c) is a good measure of long term glucose control and can be used to evaluate the glucose over a 3 to 4 month average (6). Postmortem HbA1c levels greater than 6.0% have been found to be correlated with a history of diabetes and with abnormal glucose levels determined in urine and vitreous humor. The determination of postmortem HbA1c levels can be helpful in determining medical impairment or incapacitation in aviation accidents (8).

Table 7. Glucose and Hemoglobin A1c Results

Case	Specimen	Glucose, mg/dL	Hemoglobin A1c, %
1	Urine	154	
	Vitreous	35	
	Blood		8.1
2	Vitreous	116	
	Urine	826	
	Blood (Iliac)		7.3
3	Vitreous	159	
	Urine	540	
	Blood (Cardiac)		9.6
4	Urine	5247	
	Blood		12.7
5	Urine	2811	
	Vitreous	67	
	Blood (Cavity)		6.7
6	Vitreous	21	
	Urine	519	
	Blood (Cardiac)		5.6
7	Urine	298	
	Blood		7.3
8	Urine	310	
	Blood (Cavity)		8.8
9	Urine	313	
	Vitreous	0	
	Blood		10.6
10	Urine	281	
	Blood (Heart)		11.4
11*	Urine	38	
	Blood		7.3

*Test performed by request

Ethanol

Ethanol, commonly referred to as alcohol, is frequently detected in forensic toxicology casework. Alcohol can decrease inhibitions, diminish attention and judgment, slow information processing, and cause drowsiness and slurred speech. As blood alcohol increases, the signs and symptoms of intoxication/impairment are more pronounced (6). In 2016, the federal limit for blood alcohol concentration for driving in all 50 states was 80 mg/dL or 0.08 % w/v. The federal limit for blood alcohol concentration for pilots is 40 mg/dL. The National Highway Traffic Safety Administration (NHTSA) performed a Drug and Alcohol Crash Risk Study in 2012 and found that drivers with an alcohol concentration at the 0.08 level were 4 times more likely to be involved in a crash compared to sober drivers (9).

Interpretation of postmortem ethanol concentrations can be a challenge due to the fact that bacteria and putrefaction processes may lead to the production of ethanol after death. It is important that forensic laboratories perform ethanol analyses on multiple biological specimens to help establish whether the blood alcohol concentration is a result of antemortem ingestion or postmortem production. The BSRL routinely analyzes more than one biological specimen if the ethanol result is greater than 10 mg/dL in the initial test.

In 2016, the laboratory received 7 cases that had a blood alcohol concentration greater than 40 mg/dL, the legal limit for operating a civil aircraft. Tissues positive for ethanol ranged from 10 – 336 mg/hg for cases received in 2016.

Table 8. Ethanol Results in Blood (Concentration > 40mg/dL)

Case	Specimen	Ethanol Concentration (mg/dL or mg/g)
1	Vitreous	141
	Urine	149
	Blood (Femoral)	126
2	Blood (Cavity)	247
	Vitreous	332
3	Urine	152
	Blood	418
	Heart	336
	Kidney	182
	Lung	309
4	Urine	17
	Blood (Cavity)	41
5	Blood	54
	Brain	71
	Muscle	60
6	Urine	134
	Blood	105
7	Blood (Cavity)	69
	Urine	17

Table 8. Ethanol Results in Tissue Samples

Tissue Type	Number of Cases	Ethanol Concentration Range, mg/hg
Brain	5	16 – 133
Heart	3	10 – 336
Kidney	1	182
Liver	6	14 – 103
Lung	2	30 – 309
Muscle	21	10 – 178

Drugs

The laboratory detects a variety of drugs that includes OTC, prescription (Rx) medications, and substances that are controlled by the federal government (CS). In 2016, the laboratory reported 122 different drugs and metabolites found in 155 cases. Any drug that is reported by the laboratory is confirmed by more than one test and is typically confirmed in more than one biological specimen, if available.

Of the 155 drug-positive cases, 63 (41%) cases were positive for an OTC medication, 63 (41%) cases were positive for CS drugs, and 103 (66%) cases were positive for RX drugs. According to a 2013 study by the Mayo Clinic, almost 70% of Americans are on at least one prescription medication and 20% are on five or more (10). Poly-drug use is a common finding in cases received by the BSRL with 106 (68%) cases positive for two or more drugs and 23 (15%) cases positive for five or more drugs.

Pilot safety is a high priority for the FAA, thus the FAA provides information to the airmen of the potential adverse effects of medications. During the medical certificate examination, the physician, known as an Airmen Medical Examiner (AME), has the responsibility to inform the airmen of any effects of medications that the applicant is taking and to counsel the airmen regarding the use of medications. There are certain medications that the AME should not issue the applicant a medical certificate without clearance from the FAA. Other medications can seriously cause decrements in pilot performance and the AME should advise the airmen to not fly while taking these medications (11). In 2016, there were 120 pilots, co-pilots, or flight instructors that were positive for one or more drugs. Of these 120 cases, 95 held a valid medical certificate while 25 had no medical certificate or it was expired.

In this report, the drugs reported by the laboratory are categorized by the common or brand name, type of drug, and as potentially impairing. Drugs were identified as potentially impairing if the drug has an FDA warning regarding adverse effects associated with use that might impair a pilot's judgement, decision-making, or reaction time. It is recognized that other drugs in Table 9 and 10 may have impairing effects but no official warning. Metabolites are also listed as potentially impairing, if the parent drug is identified as potentially impairing. All illegal substances are classified as potentially impairing.

Table 9. OTC Drugs Identified by the Laboratory

Drug Identified by Laboratory	Common Brand or Trade Name	Drug Type	Potentially impairing
Acetaminophen	Tylenol, Paracetamol	Non-sedating Pain Reliever	
Albuterol	ProAir HFA	Asthma Medication	
Cetirizine	Zyrtec	Sedating Antihistamine	✓
Chlorpheniramine	Chlor-Trimeton	Sedating Antihistamine	✓
Dextromethorphan	Robitussin	Non-sedating Cold/Cough Medicine	
Dextrorphan	Robitussin and metabolite of dextromethorphan	Non-sedating Cold/Cough Medicine	
Diphenhydramine	Benadryl, Unisom, Nytol	Sedating Antihistamine	✓
Doxylamine	Aldex, Unisom, NyQuil	Sedating Antihistamine	✓
Ephedrine	Ephedrine	Diet Aid	✓
Hydroxyzine	Atarax, Vistaril	Sedating Antihistamine	✓
Ibuprofen	Advil, Motrin	Non-sedating Pain Reliever	
Meclizine	Antivert	Nausea Drug	✓
Naproxen	Naprosyn, Aleve	Non-sedating Pain Reliever	
Pseudoephedrine	Sudafed	Non-sedating Cold/Cough Medicine	
Salicylate	Metabolite of aspirin	Blood Thinner	
Azacyclonol	Metabolite of Allegra	Non-sedating Allergy Medicine	
Fexofenadine	Allegra	Non-sedating Allergy Medicine	
Ranitidine	Zantac	Non-sedating Stomach Aid	

Table 10. Rx Medications Identified by the Laboratory

Drug Identified by Laboratory	Common Brand or Trade Name	Drug Type	Potentially impairing
6-Beta-Naltrexol	Metabolite of naltrexone	Opiate antagonist	
Alfuzosin	Uroxatral	Prostate/Erectile Dysfunction Drug	
Amitriptyline	Vanatrip, Elavil, Endep	Antidepressant	✓
Amlodipine	Norvasc	Cardiovascular	
Atenolol	Tenormin	Cardiovascular	
Atorvastatin	Lipitor	Cholesterol lowering	
Benazepril	Lotensin	Cardiovascular	
Bisoprolol	Zebeta	Cardiovascular	
Bupropion	Wellbutrin, Zyban	Antidepressant	✓
Bupropion Metabolite	Metabolite of Wellbutrin, Zyban	Antidepressant	✓
Buspirone	Buspar, Vanspar	Psychotropic Drug	✓
Carbamazepine	Carbatrol, Tegretol	Anti-Seizure	✓
Carvedilol	Coreg	Cardiovascular	
Chlorthalidone	Thalitone, Hygroton	Cardiovascular	
Citalopram	Celexa	Antidepressant	✓
Clomipramine	Anafranil	Psychotropic Drug	
Clonidine	Catapres, Kapvay	Cardiovascular	
Clopidogrel	Plavix	Blood Thinners	
Clozapine	Clozaril, FazaClo	Antipsychotic Drug	
Cyclobenzaprine	Flexeril	Sedating Pain Reliever	✓
Desmethylsertraline	Metabolite of Zoloft	Antidepressant	✓
Desmethylsildenafil	Metabolite of Revatio, Viagra	Prostate/Erectile Dysfunction Drug	
Diclofenac	Voltaren, Cambia, Solaraze	Non-sedating Pain Reliever	
Diltiazem	Cardizem	Cardiovascular	
Donepezil	Aricept	Neurologic Drug	✓
Doxazosin	Cardura, Doxadura, Cascor	Cardiovascular	
Doxepin	Sinequan	Psychotropic Drug	✓
Etomidate	Amidate, Hypnomidate	Anesthetic	
Fluoxetine	Prozac, Rapiflux, Sarafem	Antidepressant	✓
Gabapentin	Neurontin	Anti-Seizure	✓
Glipizide	Glucotrol, Glipizide	Diabetes Drug	
Irbesartan	Avapro	Cardiovascular	
Levamisole	Ergamisol	Antiparasitic Drug	

Table 10 Continued. Rx Medications Identified by the Laboratory

Drug Identified by Laboratory	Common Brand or Trade Name	Drug Type	Potentially impairing
Levetiracetam	Keppra	Anti-Seizure	✓
Lidocaine	Lidoderm, Xylocaine	Cardiovascular	
Losartan	Cozaar	Cardiovascular	
Metoprolol	Lopressor, Toprol	Cardiovascular	
Minoxidil	Loniten	Cardiovascular	
Naltrexone	Revia, Vivitrol	Opiate antagonist	
N-Desmethylcitalopram	Metabolite of Celexa	Antidepressant	✓
N-Desmethylclomipramine	Metabolite of Anafranil	Psychotropic Drug	
Norcyclobenzaprine	Metabolite of Flexeril	Sedating Pain Reliever	
Nordiazepam	Nordaz, Metabolite of Valium	Benzodiazepines	✓
Nordoxepin	Metabolite of Sinequan	Psychotropic Drug	✓
Norfluoxetine	Metabolite of Prozac, Rapiflux, Sarafem	Antidepressant	✓
Nortriptyline	Pamelor, Aventyl	Antidepressant	✓
Norverapamil	Calan SR, Isoptin SR, Verelan	Cardiovascular	
O-Desmethylvenlafaxine	Metabolite of Effexor	Antidepressant	
Ondansetron	Zofran	Anti-nausea Drug	
Pioglitazone	Actos	Diabetes Drug	
Pravastatin	Pravachol	Cholesterol lowering	
Propranolol	Inderol	Cardiovascular	
Quetiapine	Seroquel	Antidepressant	✓
Quinine	Qualaquin, Quinamm	Antimalaria	
Rosuvastatin	Crestor	Cholesterol lowering	
Sertraline	Zoloft	Antidepressant	✓
Sildenafil	Revatio, Viagra	Prostate/Erectile Dysfunction Drug	
Sitagliptin	Januvia	Diabetes Drug	
Sotalol	Betapace, Sorine	Cardiovascular	
Tamsulosin	Flomax	Prostate/Erectile Dysfunction Drug	
Telmisartan	Micardis	Cardiovascular	
Terazosin	Hytrin	Prostate/Erectile Dysfunction Drug	
Ticlopidine	Ticlid	Blood Thinners	
Trazodone	Oleptro, Desyrel	Psychotropic Drug	✓
Triamterene	Dyrenium	Cardiovascular	
Valsartan	Diovan	Cardiovascular	
Venlafaxine	Effexor	Antidepressant	✓
Verapamil	Calan SR, Isoptin SR, Verelan	Cardiovascular	
Warfarin	Coumadin	Blood Thinners	

Table 11. CS Identified by the Laboratory

Drug Identified by Laboratory	Common Brand or Trade Name	Drug Type	Potentially impairing
Alpha-Hydroxyalprazolam	Metabolite of Xanax	Benzodiazepines	✓
Alprazolam	Xanax	Benzodiazepines	✓
Amphetamine	Adderall, Metabolite of methamphetamine	Illicit	✓
Anhydroecgonine Methyl Ester	Metabolite of cocaine	Illicit	✓
Benzoylecgonine	Metabolite of cocaine	Illicit	✓
Butalbital	Fiorinal	Migraine Drugs	✓
Cocaethylene	Metabolite of cocaine if ethanol present	Illicit	✓
Cocaine	Cocaine	Illicit	✓
Codeine	Codeine, Metabolite of morphine	Opioids	✓
Desmethyltramadol	Metabolite of Ultram	Sedating Pain Reliever	✓
Diazepam	Valium	Benzodiazepines	✓
Dihydrocodeine	Metabolite of hydrocodone	Opioids	✓
Ecgonine Methyl Ester	Metabolite of cocaine	Illicit	✓
Fentanyl	Sublimaze	Opioids	✓
Hydrocodone	Lortab, Vicodin, Norco	Opioids	✓
Hydromorphone	Dilaudid, Metabolite of hydrocodone	Opioids	✓
Ketamine	Ketalar	Anesthetic	✓
Lorazepam	Ativan	Benzodiazepines	✓
Meprobamate	Equanil, Miltown	Psychotropic Drug	✓
Methadone	Diskets, Dolophine	Opioids	✓
Methamphetamine	Methamphetamine	Illicit	✓
Methylphenidate	Ritalin	Neurologic Drug	✓
Midazolam	Versed	Benzodiazepines	✓
Morphine	Avinza, Kadian, MS Contin	Opioids	✓
Modafinil	Provigil	Treatment of Narcolepsy	
Norketamine	Metabolite of Ketalar	Anesthetic	✓
Oxazepam	Serax, Metabolite of Valium	Benzodiazepines	✓
Oxycodone	Percocet, Roxicet, Tylox	Opioids	✓
Oxymorphone	Opana, Metabolite of oxycodone	Opioids	✓
Temazepam	Restoril, Metabolite of Valium	Benzodiazepines	✓
Tetrahydrocannabinol	Marijuana, Marinol	Illicit	✓
Tetrahydrocannabinol Carboxylic Acid	Metabolite of marijuana	Illicit	✓
Tramadol	Ultram	Sedating Pain Reliever	✓
Zolpidem	Ambien	Sleep Aid	✓

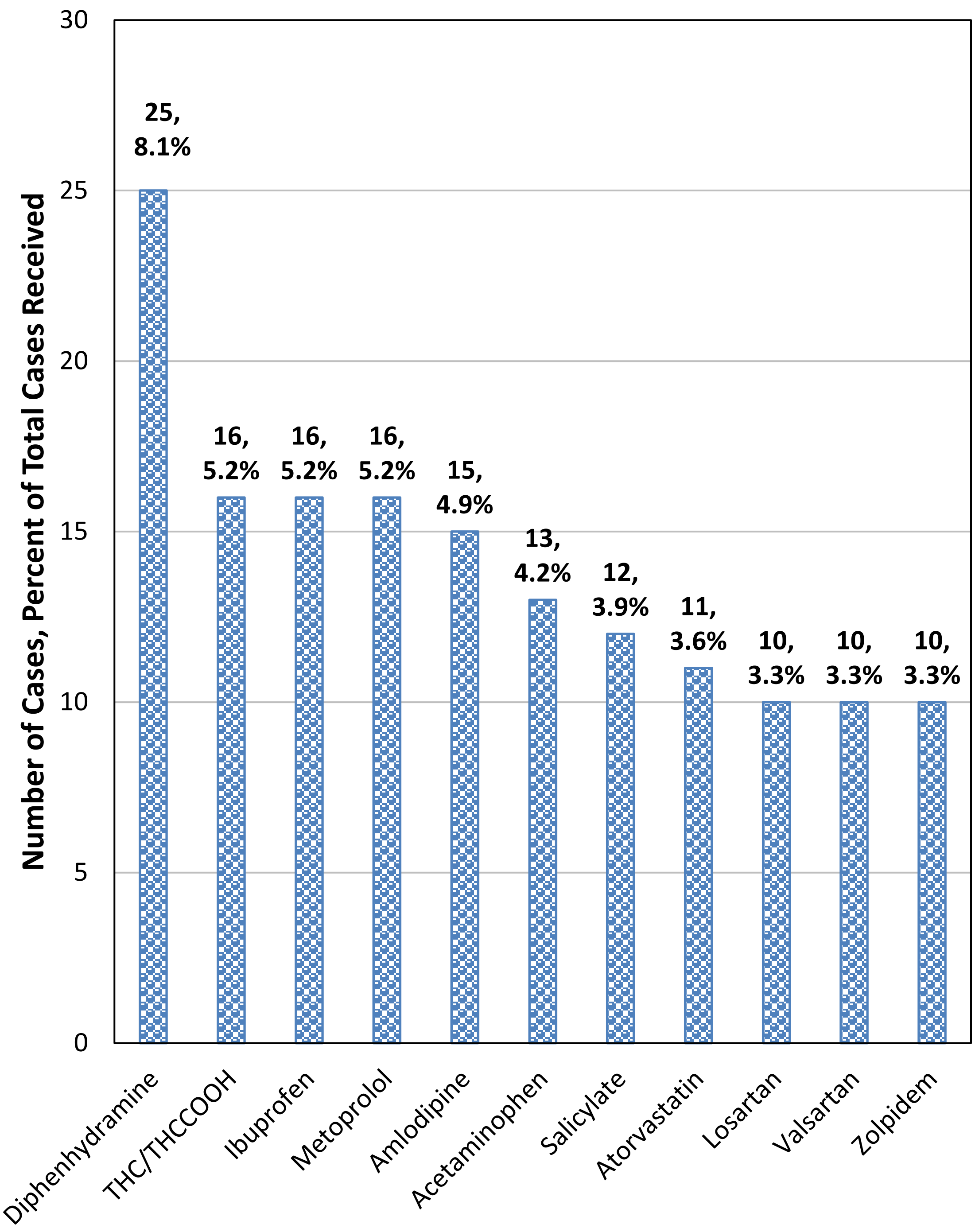


Figure 18. Most Common Drugs Detected, Total Cases=307

Medical Certificate – Valid vs. None

The NTSB evaluated toxicology findings of fatally injured pilots between 1990 and 2012 in a Safety Study to assess the trends in the prevalence of OTC, Rx, and illicit drugs use by pilots. The NTSB found that pilots who did not have a valid medical certificate were more likely to have a positive result for a potentially impairing drug or a controlled substance than those pilots who had a valid medical certificate (12). In 2016, the laboratory analyzed 216 pilots, co-pilots, or flight instructors for the presence of drugs. Of these pilots, co-pilots, or flight instructors, 180 held a valid medical certificate and 36 had no medical certificate or it was expired. The laboratory found similar results in 2016 to the NTSB study in that a pilot with no medical certificate was more likely to be positive for any drug (69%) and positive for a potentially impairing drug (47%).

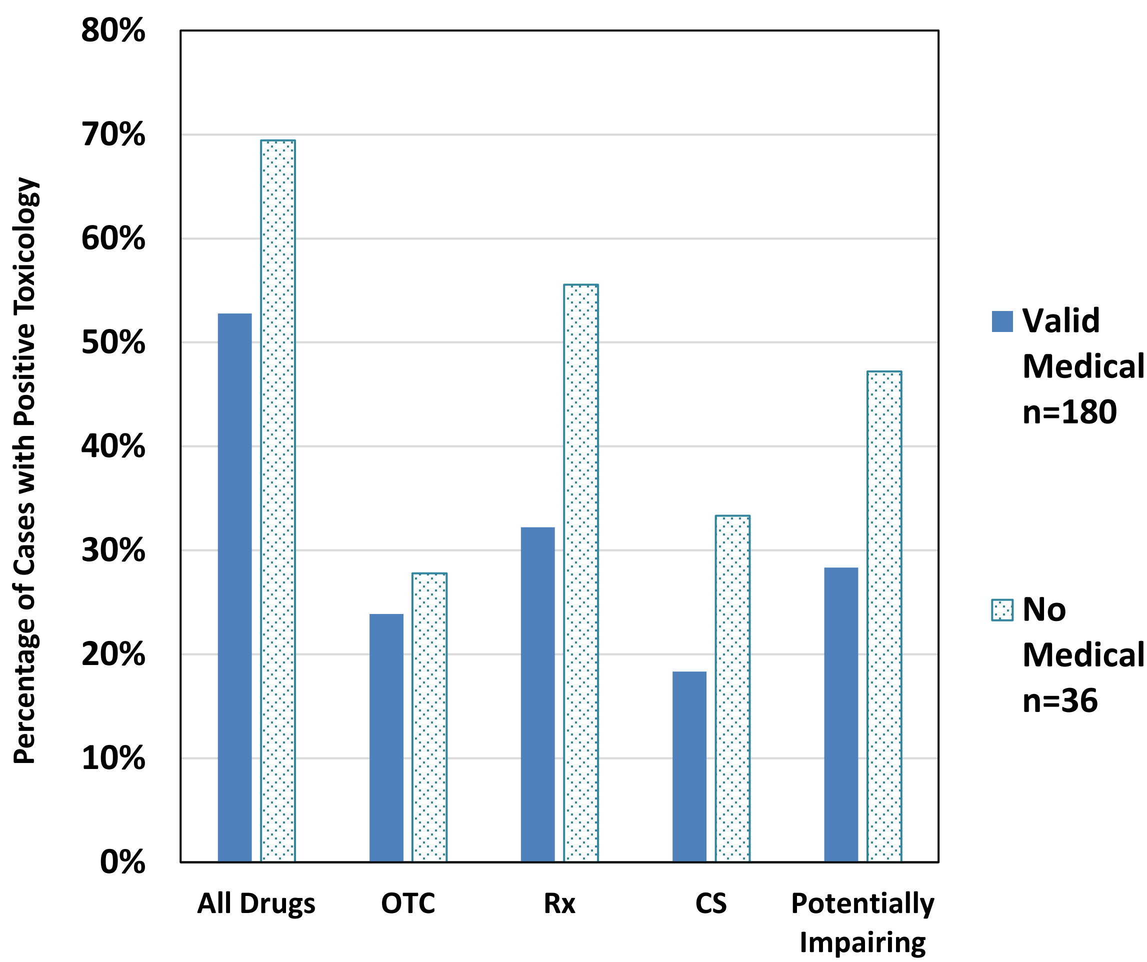


Figure 19. Positive Toxicology Findings Classified by Medical Certificate Status

Diphenhydramine

Diphenhydramine was the most commonly identified drug in the laboratory in 2016 - 25 (8.1%) cases. Diphenhydramine is an antihistamine found in more than 50 different OTC and Rx medications, and is used to relieve symptoms of allergy, hay fever, and the common cold. Normal side effects of diphenhydramine use includes drowsiness, dizziness, headache, irritability, decreased coordination and dry mouth/nose/throat/eyes.

The normal dosage range for diphenhydramine is 25 to 50 mg every 4 – 6 hours. Single dosage and continuous dosage result in blood concentrations ranging from 50 – 100 ng/mL. Toxic levels range from 1000 – 2000 ng/mL, with comatose/fatal levels rising above 5000 ng/mL (13). Sedative effects can be expected with blood concentrations above 50 ng/mL (14). Diphenhydramine found at sedating levels in pilots involved in civil aviation accidents is of concern to the FAA. Findings reported by the laboratory are used to create and refine policies issued by the FAA regarding use of the medication.

Use of more than the recommended amount of diphenhydramine can increase side effects to a noticeable degree and the individual may be perceived as drunk. Geriatric use of diphenhydramine can increase side effects at normal dosage (15). Diphenhydramine can cause central nervous system depression which can impair driving or the operation of heavy machinery; therefore, the FAA advises that pilots should wait 30 hours after the last dosage of diphenhydramine before piloting an aircraft (16).

Table 12 lists the results for the cases that were positive for diphenhydramine. In some cases, a quantitative value was not determined from the testing. Those results are reported by the laboratory as "detected" because the drug was identified and confirmed by the toxicology analyses but a concentration was not reported.

Table 12. Diphenhydramine Results

Case	Specimen	Diphenhydramine concentration, ng/mL
1	Liver	Detected
	Muscle	Detected
2	Liver	Detected
	Kidney	Detected
3	Blood (Cavity)	69
	Urine	Detected
4	Urine	Detected
	Blood (Cardiac)	0
5	Liver	Detected
6	Liver	Detected
	Blood (Cavity)	326
7	Urine	Detected
	Blood (Heart)	24
8	Urine	Detected
	Blood	200
9	Urine	Detected
	Blood	30
10	Liver	Detected
	Blood (Cavity)	Detected
11	Urine	Detected
	Blood	Detected
12	Urine	Detected
	Blood (Cavity)	0
13	Urine	Detected
	Blood (Cavity)	Detected

Table 12 Continued. Diphenhydramine Results

Case	Specimen	Diphenhydramine concentration, ng/mL
14	Urine	Detected
	Blood	49
15	Blood (Cavity)	0
	Urine	Detected
16	Muscle	Detected
	Lung	Detected
17	Blood (Cardiac)	0
	Urine	Detected
18	Blood (Heart)	51
	Urine	Detected
19	Muscle	Detected
	Blood (Heart)	Detected
20	Lung	Detected
	Liver	Detected
21	Blood (Heart)	Detected
	Urine	Detected
22	Blood (Iliac)	13
	Urine	Detected
23	Liver	Detected
	Urine	Detected
24	Liver	Detected
	Blood (Cavity)	0
25	Urine	Detected
	Blood (Heart)	Detected

Marijuana

According to the National Institute on Drug Abuse (NIDA), 46.2% of individuals 26 or older have used marijuana in their lifetime (17). Marijuana is often used for its euphoric effects and medicinal properties, but numerous studies have shown that the use of marijuana impairs an individual's ability to efficiently complete everyday tasks by impairing memory and concentration and by increasing reaction time (6). An individual who operates a motor vehicle while smoking marijuana has a 2-fold increase of being involved in a motor vehicle accident (18). The impairment associated with marijuana use has become a worldwide public safety concern, especially due to the legalization for medicinal and/or recreational use in many states. The use of marijuana and operating a motor vehicle varies by state from zero tolerance to per se laws of 2 or 5 ng/mL; however, the FAA has zero tolerance and does not permit safety-sensitive transportation employees, which includes pilots, to use marijuana recreationally or medicinally under 49 CFR Part 40, at 40.151(e) (19,20).

One of the primary compounds that is responsible for these side effects is Δ^9-tetrahydrocannabinol, or THC. This lipophilic compound is quickly metabolized into 11-hydroxy-tetrahydrocannabinol (11-OH-THC), which has also been found to be psychoactive, and further metabolized into the inactive metabolite 11-nor- Δ^9-carboxy-tetrahydrocannabinol (THCCOOH), which can be detected for an extended period of time. (6). Marijuana use is determined by detection and reporting of THC and/or THCCOOH. THC/THCCOOH was the most commonly found controlled substance by the laboratory in 2016 – 16 cases (5.2%).

Table 13 shows the concentration for the marijuana-positive cases. The average age for marijuana-positive cases is 41.5 with a minimum age of 17 and a maximum age of 65 (Table 14). Accidents that involve marijuana happen all over the U.S. with 38 % (N=6) occurring in the western region of the country (Figure 20).

Table 13. Marijuana Results

Case	Specimen	THC	THCCOOH
1	Blood (Cavity)	56.9	21.5
	Brain	22.3	25.4
	Lung	1,374	102
	Liver	122	1,361
	Urine	--	807.2
2	Lung	52.9	18.8
	Liver	35.2	50.4
	Muscle	Detected	Detected
3	Blood	0	12.3
4	Blood (Cavity)	9.4	10
	Brain	7.7	5.3
	Lung	19.4	14
	Liver	22.1	244.7
5	Blood		11.1
6	Blood (Cavity)	Detected	6.1
	Brain	0	2.6
	Liver	Detected	35.1
	Urine	--	58
7	Blood (Cavity)	0	1.7
	Lung	Detected	Detected
	Liver	Detected	12.4
	Urine	--	20.3
8	Blood	0	20.3
9	Blood (Heart)		2.1
	Brain		Detected
	Urine	--	31
10	Blood		15.6
11	Blood (Cavity)	0	7.4
	Brain		2.3
	Liver	32.4	28.5
	Urine	--	109.2
12	Blood (Femoral)	0	2.7
	Liver		Detected
	Lung	Detected	Detected
	Urine	--	76.8
13	Blood	10.1	13.1
	Urine	--	48.1
14	Blood	10.6	24.8
	Lung	Detected	40.5
15	Blood (Cavity)	Detected	7.1
	Lung	Detected	48.7
16	Blood (Cavity)	4.5	5.5
	Liver		40.1
	Urine	--	67.9

Table 14. Age Statistics of Marijuana Positive Cases

Age Minimum	Age Maximum	Age Mean	Age Standard Deviation
17	65	41.5	14.8

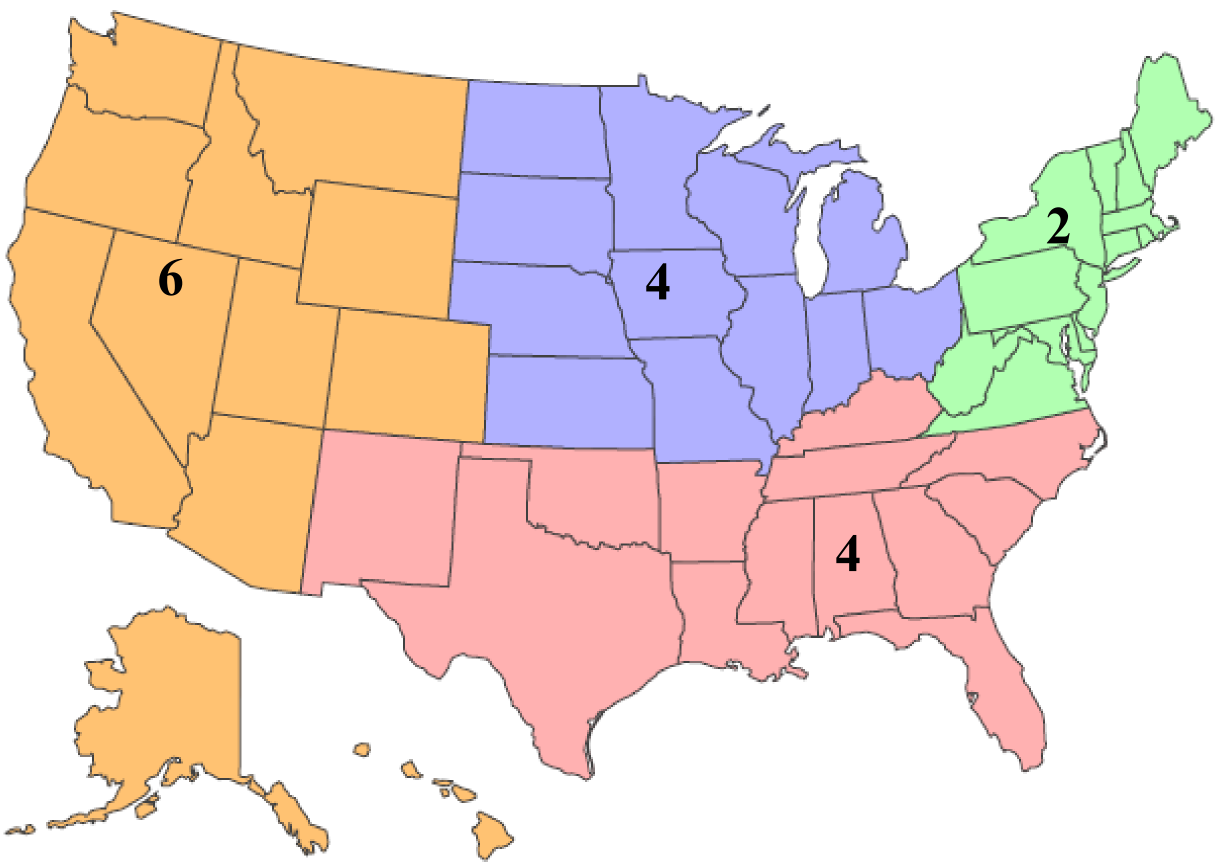


Figure 20. Marijuana Positive Cases Classified by U.S. Region

Blood Pressure Medications

High blood pressure, also known as hypertension, occurs when blood flows through blood vessels at a higher than normal pressure. This condition can cause damage to the blood vessels or heart. It can also result in heart attack, stroke, and/or death (21). There are several classes of blood pressure medications including: diuretics, beta-blockers, ACE inhibitors, angiotensin II receptor blockers, calcium channel blockers, alpha-blockers, alpha-2 receptor agonists, central agonists, peripheral adrenergic inhibitors, and blood vessel dilators. In 2016, the blood pressure medications detected by the laboratory include amlodipine, atenolol, benazepril, bisoprolol, carvedilol, chlorthalidone, clonidine, diltiazem, doxazosin, irbesartan, losartan, metoprolol, minoxidil, propranolol, sotalol, telmisartan, terazosin, triamterene, valsartan, and verapamil. High blood pressure medications was the most common class of prescription medications detected by the laboratory in 2016. Of the 155 cases that were positive for drugs, 52 (33.5%) had one or more blood pressure medication in their system at the time of the accident.

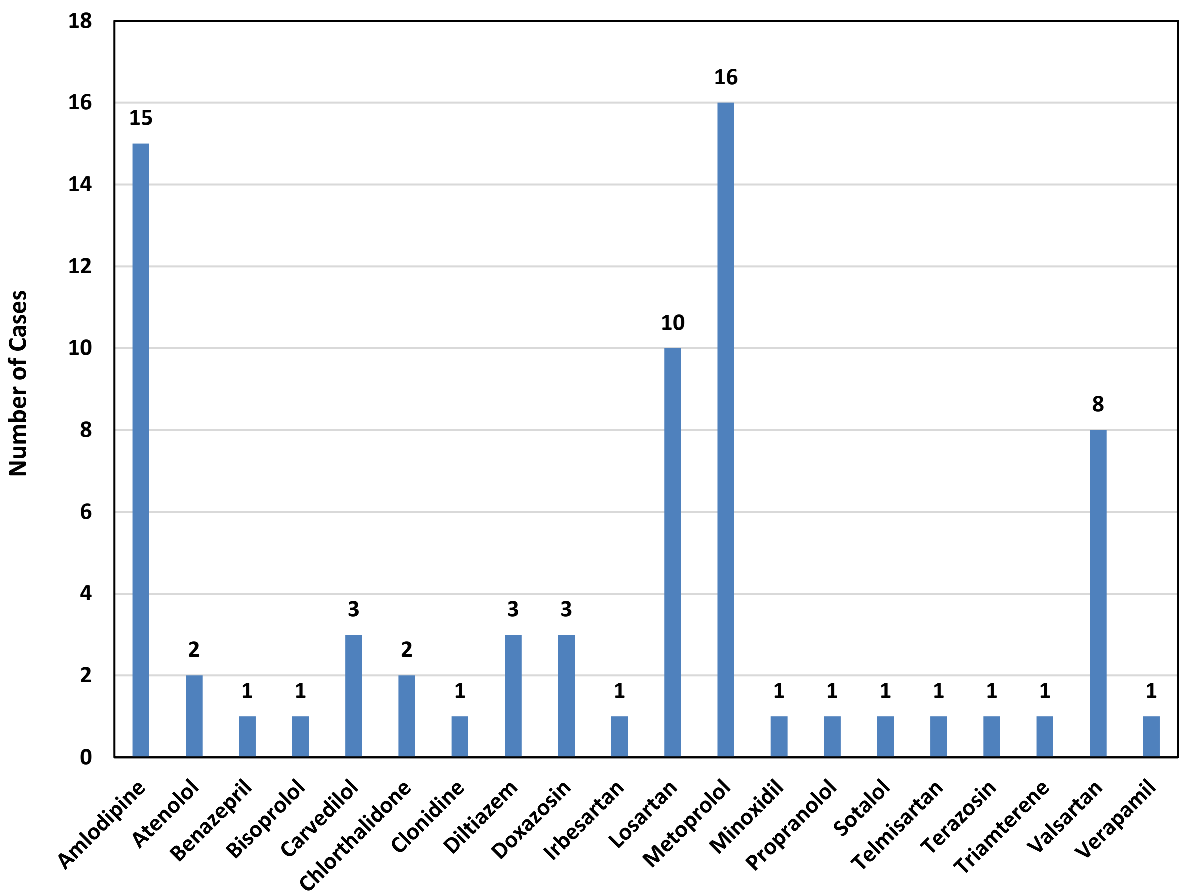


Figure 21. Blood Pressure Medications Detected

Five-Year Comparisons

Comparisons of data for a five-year period have been used by the AAM-600 Research Division, the NTSB, and the FAA to monitor accident and drug trends for aviation accidents in the United States (22-26). The NTSB uses data about the prevalence of OTC, prescription, and illicit drug use from fatally injured pilots to recommend safety improvements for pilots (12). The following graphs and figures show the trends observed by the laboratory over a five-year period for the number of cases received, number of non-aviation accidents received, number of female pilots received, number of accidents involving lightsport aircraft, number of nonfatal cases received, and the percentage of cases with positive toxicology findings.

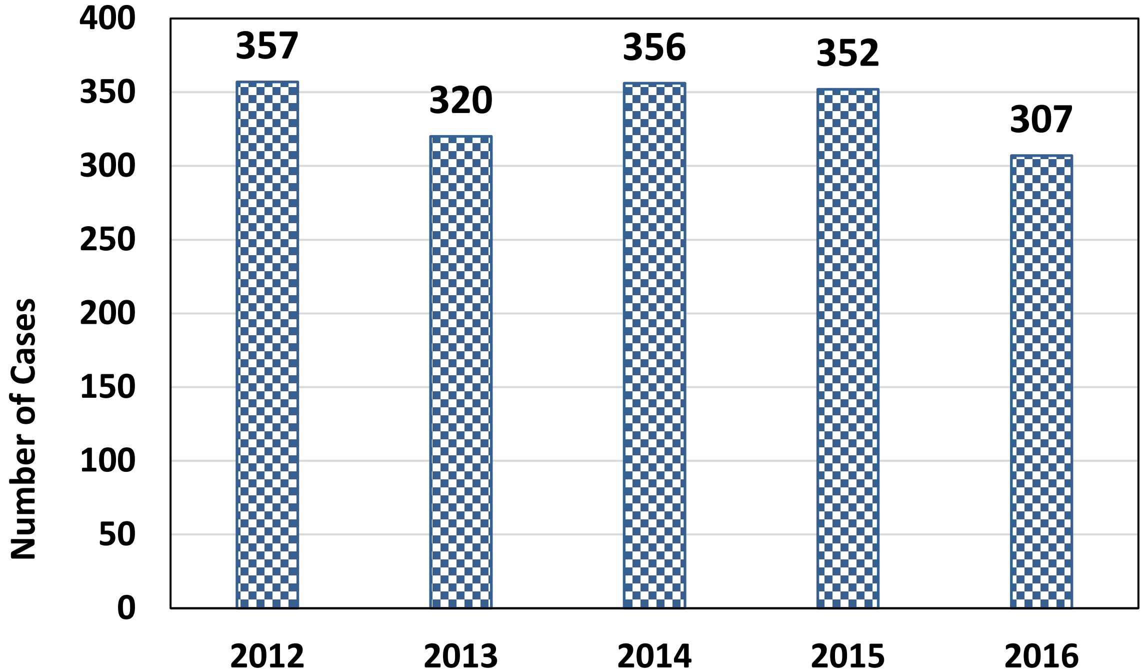


Figure 22. Five-Year Comparison: Number of Cases Received

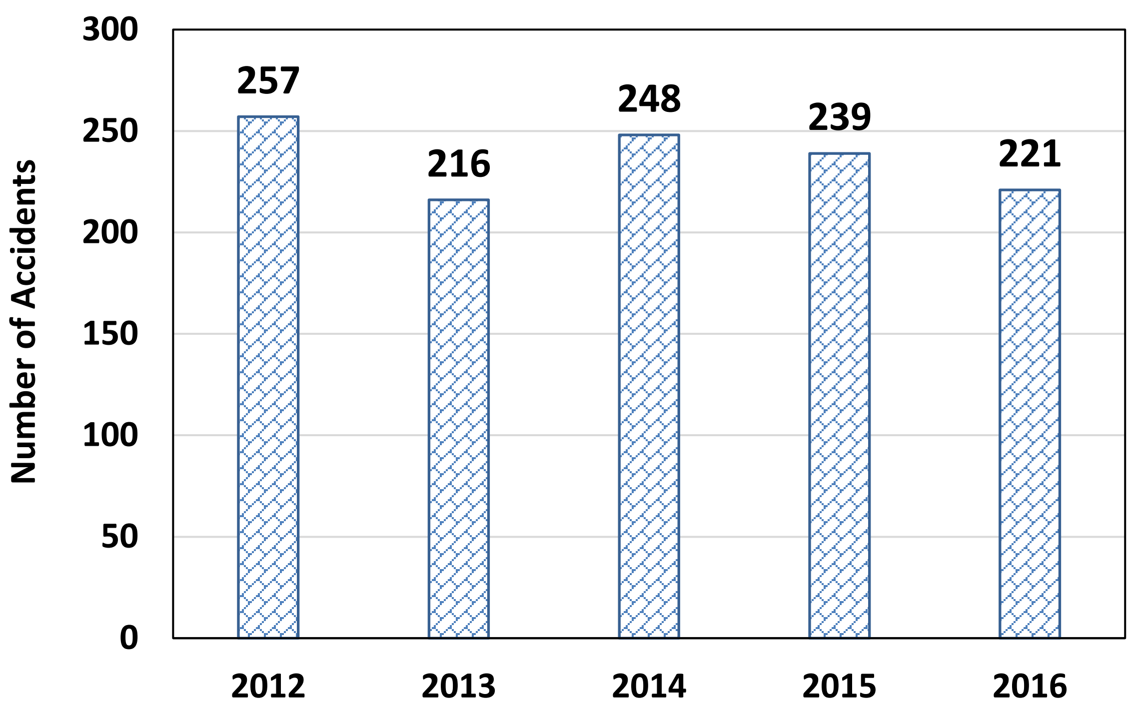


Figure 23. Five-Year Comparison: Number of Aviation Accidents

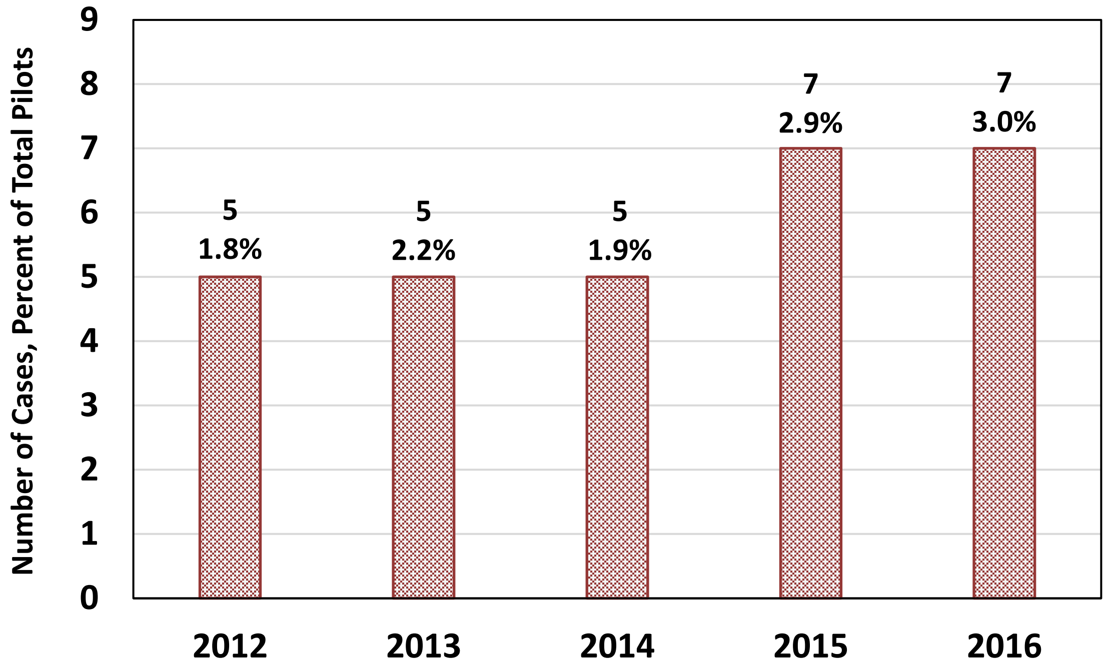


Figure 24. Five-Year Comparison: Number of Female Pilots Received

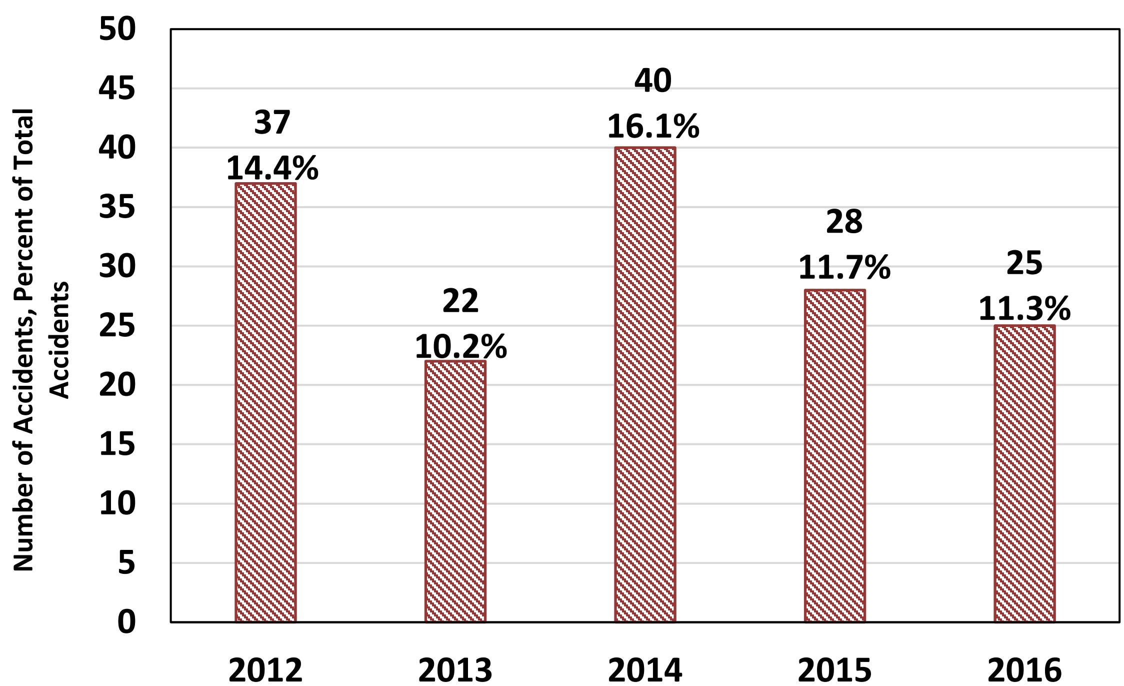


Figure 25. Five-Year Comparison: Number of Lightsport Aircraft Accidents

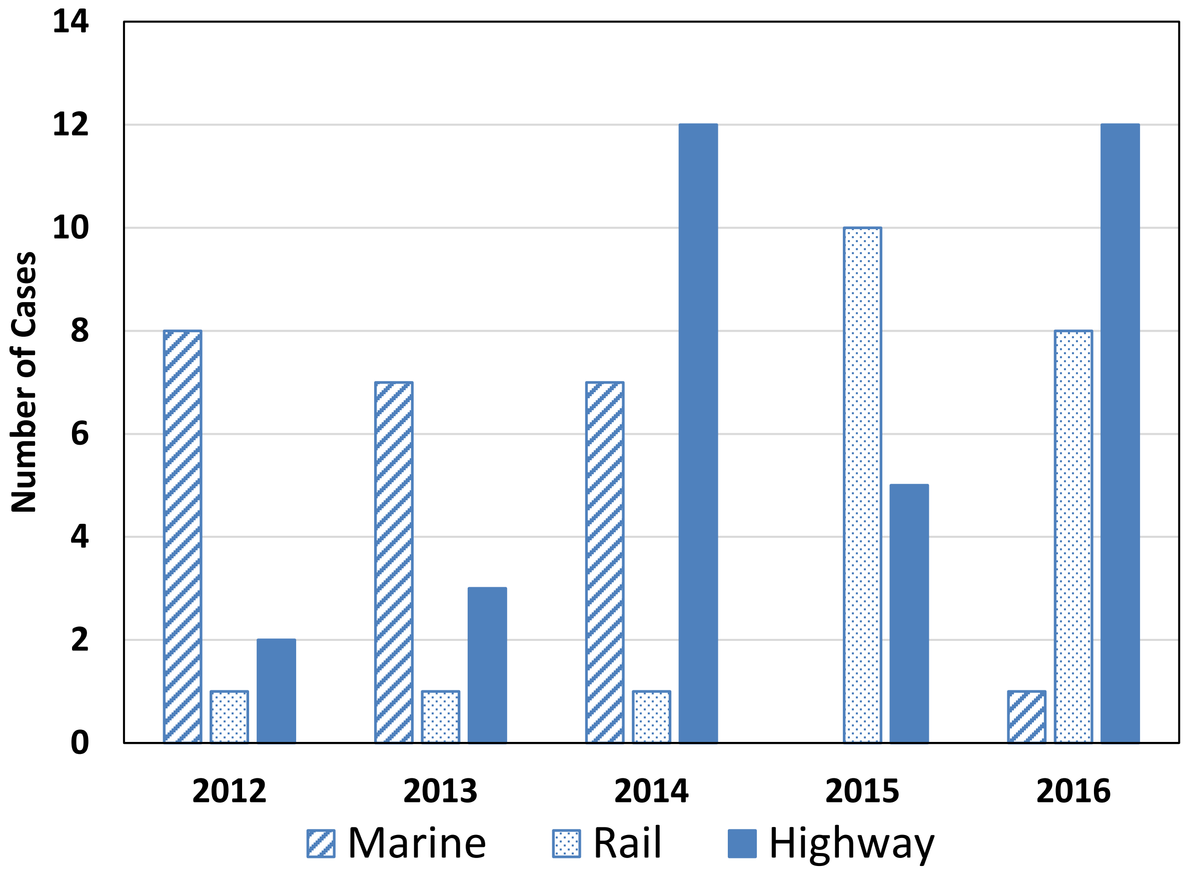


Figure 26. Five-Year Comparison: Number of Non-Aviation Accidents Received

Table 15. Five-Year Comparison: Percent of Non-Aviation Accidents

Year	Percent of Total Cases Received
2012	3.1%
2013	3.4%
2014	5.6%
2015	4.3%
2016	6.8%

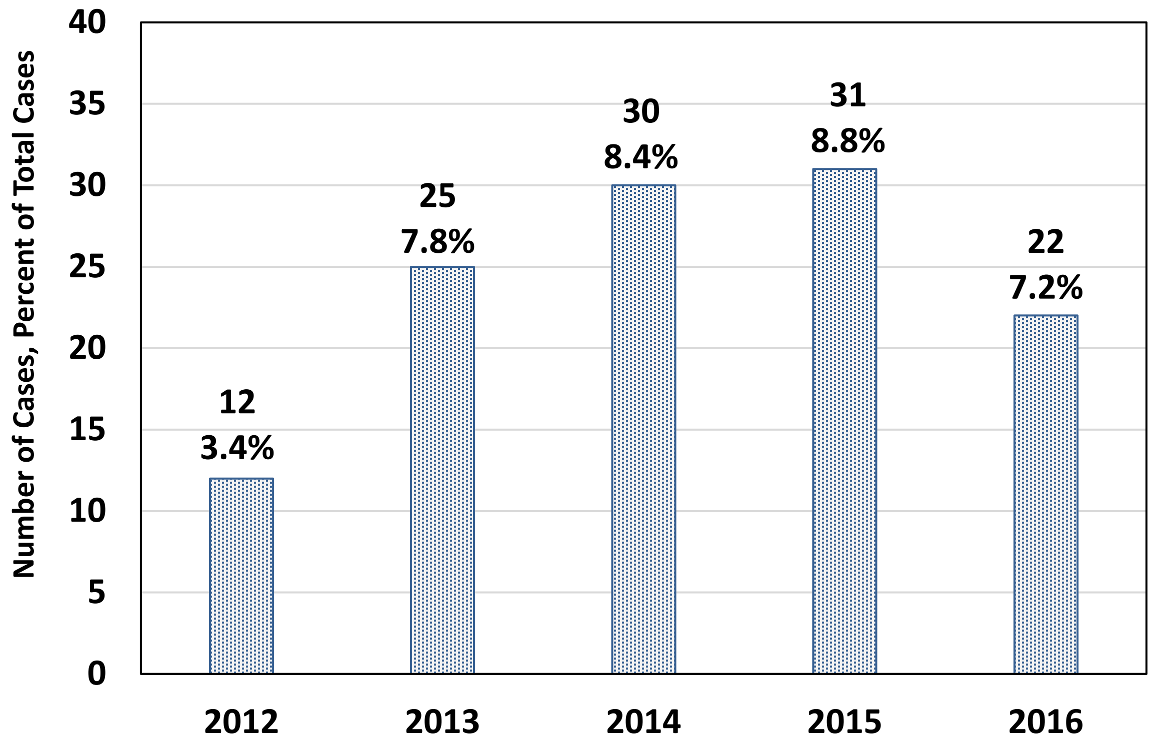


Figure 27. Five-Year Comparison: Number of Nonfatal Cases Received

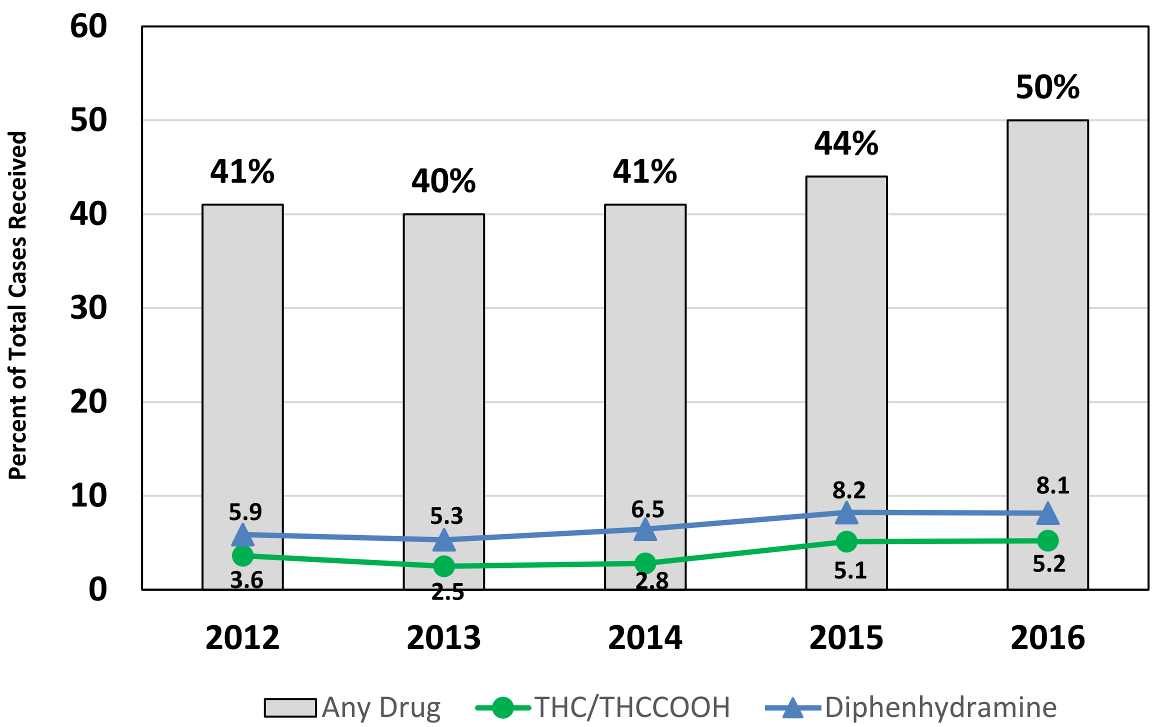


Figure 28. Five-Year Comparison: Percent of Positive Toxicology

DISCUSSION

This report identifies descriptive characteristics of all accident cases, including aviation, highway, rail, and marine modes of transportation, that the Forensic Toxicology Section received in 2016. It is the first report to provide information regarding the non-aviation accidents the laboratory handles each year. While this report contains numerous characteristics about the cases, the editors have chosen to highlight several that are of interest and significance to the FAA and NTSB.

The number of cases received by the laboratory has decreased over a five-year period from a high of 357 in 2012 to 307 in 2016 (Figure 22). The number of aviation accidents has also decreased from 257 to 221 accidents over the same time period (Figure 23). Although aviation accidents have slightly decreased, the percentage of cases the laboratory received from other modes of transportation has increased from 3.1% in 2012 to 6.8% in 2016 (Table 15). The number of nonfatal cases received per year has fluctuated over the five-year period from 3.4% to 8.8% (Figure 27).

For aviation accidents, the majority of the pilots, co-pilots, or flight instructors received by the laboratory were male (97%). Only 8 cases (3.0%) in 2016 were females that were identified as the pilot, co-pilot or flight instructor. The percentage of female pilot cases has increased from 1.8% in 2012 to 3.0% in 2016 (Figure 24). The average age for pilots, co-pilots, and flight instructors is 55.1 years in the present study. During 2016, there were 560,152 active airmen in the FAA registry with an average age of 44.3 years. Table 3 and Figure 9 shows that 28.7% of the cases received by the laboratory were 65 years and older, while only 10.97% of the active airmen are 65 years and older, suggesting that older pilots are more likely to be involved in a fatal aviation accident.

The FAA sets standards and procedures for pilots to obtain a valid medical certificate in order to exercise the privileges of an airline transport, a commercial, or a private pilot. An active airman can obtain a first-class, second-class, or third-class medical certificate for flying commercial or private aircraft. Sport pilots are not required to maintain a valid medical certificate and may operate a lightsport aircraft, glider, or ultralight. In 2016, the laboratory received 182 cases from accidents that required the pilot to hold a valid medical certificate. The majority (92%) of the pilots, co-pilots, or flight instructors held a current medical certificate, while 14 cases (8%) had been denied or had an expired medical certificate (Figure 10). Almost half (48%) of the pilots with a current medical certificate were Third-Class or private pilots, while 14% of the cases were First-Class pilots (Figure 11). In regards to positive toxicology findings and medical certification, a pilot with no medical certificate was more likely to be positive for drugs than a pilot with a valid medical certificate (Figure 19). The results are similar to the NTSB study that found that pilots who did not have a valid medical certificate were more likely to have a positive result for a potentially impairing drug or a controlled substance than those pilots who had a valid medical certificate. Because pilots without a medical certificate are more likely to be positive for impairing drugs, there appears to be an increased risk of an accident for these pilots (11).

Toxicology analyses over the last five years has shown an increase in the percent of cases positive for at least one OTC, RX, or CS drug (Figure 28). The most common drug identified by the laboratory in 2016 was diphenhydramine, an antihistamine with potential impairing side effects. The prevalence of diphenhydramine detected in cases has increased from 5.9% to 8.1% during the five-year period from 2012 to 2016, respectively. Due to the continued increase of diphenhydramine positive cases seen by the laboratory from pilots involved in fatal aviation accidents, the FAA has taken a number of steps to educate pilots and AME's on the potential performance impairment that can occur after the use of diphenhydramine.

CONCLUSION

In summary, during 2016, the BSRL received 307 cases from accidents in various modes of transportation including aviation, highway, marine, and rail. This total includes select United States and Canada military aviation accidents, and an international accident from the Bahamas. The laboratory received biological specimens from 22 incidents in which the pilot, driver, or primary operator was nonfatal. Toxicological analysis was performed on 296 cases, 19 of which were analyzed only for carboxyhemoglobin. Of the 277 cases that were analyzed for drugs, 122 were negative and 155 were positive for at least one drug.

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