Critical tables for calculating the cholesterol saturation of native bile

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Abstract A simple method for the rigorous derivation of lithogenic index or percent cholesterol saturation, embodying both relative and total lipid concentrations, is described. We recently demonstrated that under physiological conditions only two key physical-chemical variables, the bile salt–lecithin ratio *and* the total lipid (bile salts + lecithin +cholesterol) concentration determine the equilibrium cholesterol solubility of bile. Of relevance to gallstone formation and dissolution in man is that the influence of variations in total lipid concentration on cholesterol solubility is quantitatively more important but has essentially been ignored. Using model biliary lipid systems, we experimentally determined a family of cholesterol solubility curves to encompass a wide range of bile salt–lecithin ratios for physiological variations in total lipid concentration (0.3–30 g/dl) at 37°C (pH 7.0, 0.15 M NaCl) and accurately fitted these with fifth degree polynomial equations. We have now solved these equations for moles percent cholesterol, i.e., [cholesterol] × 100/[bile salt] + [lecithin] + [cholesterol] employing physiological values (0.085–0.425) for molar [lecithin]/[bile salt] + [lecithin] ratios. The resulting tables provide precise values for the maximal amount of cholesterol that would be soluble in bile at any total lipid concentration and bile salt–lecithin ratio and allow for rapid and accurate calculation of lithogenic index or percent cholesterol saturation from the moles percent cholesterol actually present in hepatic, gallbladder, and duodenal biles.

Supplementary key words bile salts · lecithin · mixed micelles · polynomial equations · triangular coordinates · ursodeoxycholate conjugates · lithocholate conjugates · conjugates of lithocholate sulfate

In order to correctly calculate the lithogenic index (1) or percent cholesterol saturation (2) of native bile, the maximal cholesterol concentration that could be solubilized at equilibrium in the bile sample or in an appropriate model system must be known. We have therefore completed (3) a systematic analysis of equilibrium cholesterol solubilities in model systems of conjugated bile salts, egg yolk lecithin, cholesterol, and aqueous solvent under a wide variety of physical-chemical conditions including those of physiological importance. We established that within physiological bile salt–lecithin ratios at 37°C, the influences of bile salt type[2] and ionic strength are small and can be ignored whereas the effects of variations in bile salt–lecithin ratio and total lipid concentration (bile salts plus lecithin plus cholesterol in g/dl or mol/1) are major factors. In fact, the bile salt–lecithin ratio varies physiologically within narrow limits, but, as the total lipid concentration can vary dramatically (<1 – ≈30 g/dl), depending on the site of collection from patient to patient and from time to time in the same patient (3–5), the influence of this variable becomes the predominant determinant of cholesterol solubility. These results demonstrate that for the precise determination of the degree of cholesterol saturation (i.e., lithogenic index or percent cholesterol saturation) of native bile, the appropriate maximal cholesterol solubility value experimentally determined for the bile salt–lecithin ratio and the total lipid concentration of each sample (at 37°C, pH 7.0, in 0.15 M NaCl) must be employed. The critical tables of moles percent cholesterol presented here were compiled to simplify these calculations.

GENERATION OF THE TABLES

Once a threshold total lipid concentration is exceeded the maximum cholesterol solubility in bile increases linearly with the logarithm of the total lipid concentration over the range of physiological bile salt–lecithin ratios (3). From these data, a series of cholesterol solubility curves corresponding to individual total lipid concentrations of 0.3–30 g/dl were developed for physiological bile salt–lecithin ratios. The curves were accurately fitted with a series of fifth degree polynomial equations whereby moles percent

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[2] This only applies to the conjugates of the common bile salts. The conjugates of ursodeoxycholate, lithocholate, and lithocholate sulfate are exceptions (see Appendix).

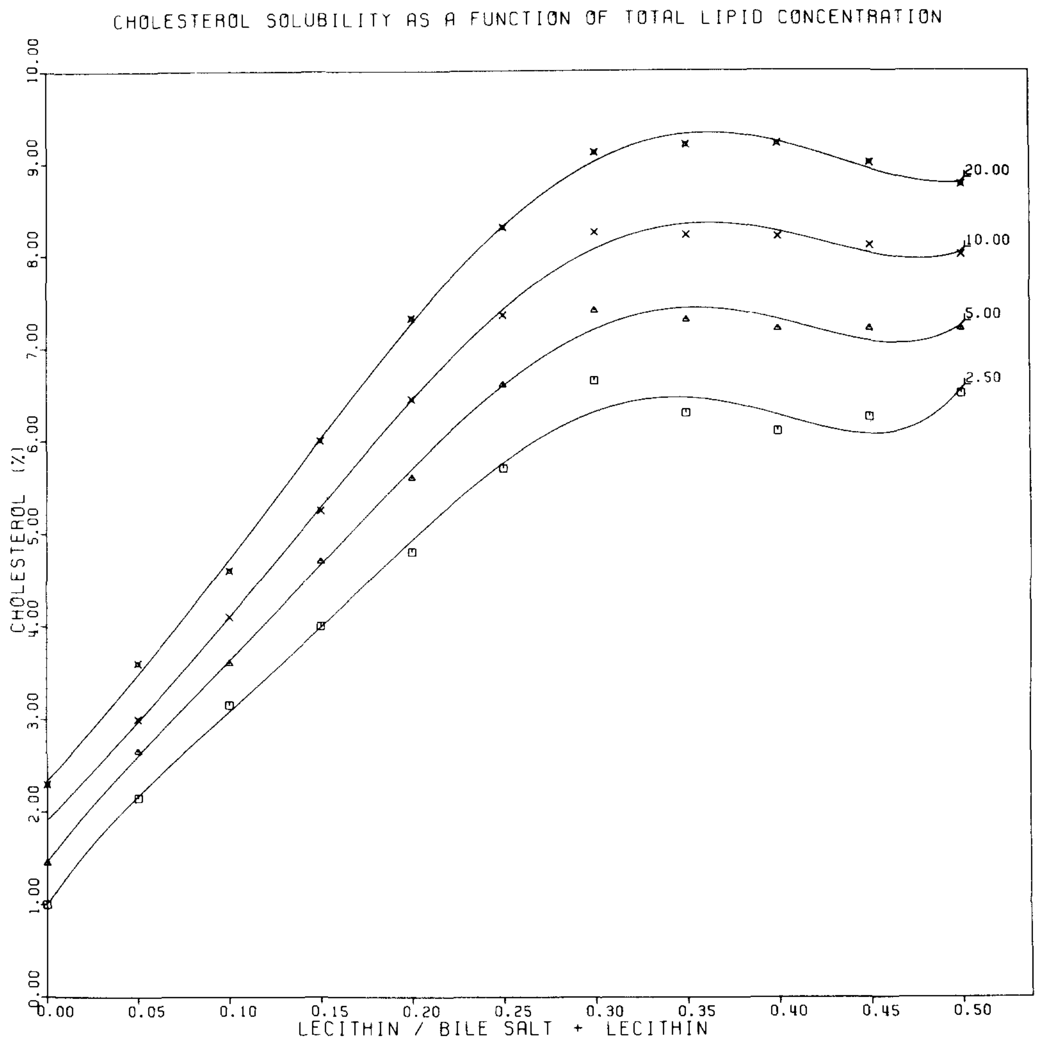

Fig. 1. Sample Calcomp 960 computer plots of experimental data and fifth degree polynomial regressions for maximal equilibrium cholesterol solubility as a function of variations in total lipid concentration and bile salt–lecithin ratio (37°C, 0.15 M NaCl, pH 7.0). The fifth degree polynomials have the form

$$y = a + bx + cx^2 + dx^3 + ex^4 + fx^5$$

where y = moles percent cholesterol, i.e., [cholesterol] × 100/[bile salt] + [lecithin] + [cholesterol] plotted on the ordinate and x = molar [lecithin]/[bile salt] + [lecithin] ratio plotted on the abscissa. Each curve is labeled with the appropriate total lipid concentration (g/dl).

cholesterol, i.e., [cholesterol] × 100/[bile salt] + [lecithin] + [cholesterol] could be derived from the molar [lecithin]/[bile salt] + [lecithin] ratio and total lipid concentration (3). Samples[3] of these polynomial regressions for four total lipid concentrations are plotted (Calcomp 960 computer plots) in rectangular format in **Fig. 1** together with the corresponding experimental cholesterol solubilities. Cholesterol saturation expressed as moles percent cholesterol, i.e., [cholesterol] × 100/[bile salt] + [lecithin] + [cholesterol], is plotted on the ordinate and molar [lecithin]/[bile salt] + [lecithin] ratio is plotted on the abscissa. The resulting graphs are very similar in appearance to the conventional triangular coordinate plots of Admirand and Small (6) but have now been mathematically transformed for plotting on rectangular coordinates as suggested by Thomas and Hofmann (7). With the use of a mini-computer, we solved to four significant figures all fifth degree polynomial equations for moles percent cholesterol, employing the physiological range of molar [lecithin]/[bile salt] + [lecithin] ratios (0.085–0.425) in 0.005 increments. The critical table (**Table 1**) therefore gives all possible values for moles percent cholesterol that would

[3] See reference 3 for the complete series.

TABLE 1. Three-place values for maximum cholesterol solubility in bile[a]

N.[b]	0.30[c]	0.35	0.40	0.45	0.50
.085	.871	1.129	1.346	1.498	1.546
.090	.915	1.188	1.422	1.579	1.636
.095	.959	1.243	1.491	1.653	1.719
.100	1.001	1.296	1.552	1.720	1.795
.105	1.041	1.346	1.606	1.780	1.865
.110	1.080	1.393	1.652	1.834	1.927
.115	1.117	1.437	1.691	1.880	1.982
.120	1.151	1.478	1.724	1.920	2.032
.125	1.183	1.516	1.751	1.954	2.075
.130	1.212	1.550	1.772	1.983	2.113
.135	1.237	1.581	1.789	2.008	2.146
.140	1.260	1.609	1.801	2.028	2.176
.145	1.278	1.633	1.809	2.045	2.202
.150	1.292	1.654	1.815	2.059	2.225
.155	1.302	1.672	1.818	2.071	2.246
.160	1.307	1.687	1.821	2.082	2.267
.165	1.307	1.697	1.822	2.092	2.287
.170	1.303	1.705	1.824	2.102	2.307
.175	1.293	1.709	1.827	2.112	2.329
.180	1.278	1.709	1.830	2.124	2.352
.185	1.257	1.706	1.836	2.138	2.378
.190	1.231	1.700	1.843	2.154	2.407
.195	1.199	1.690	1.853	2.173	2.439
.200	1.161	1.677	1.866	2.195	2.475
.205	1.118	1.661	1.882	2.220	2.515
.210	1.069	1.640	1.900	2.248	2.559
.215	1.015	1.617	1.920	2.280	2.608
.220	.956	1.589	1.943	2.315	2.660
.225	.892	1.558	1.967	2.352	2.717
.230	.823	1.523	1.991	2.391	2.777
.235	.750	1.484	2.015	2.433	2.839
.240	.674	1.442	2.038	2.474	2.904
.245	.594	1.395	2.058	2.516	2.970
.250	.511	1.343	2.072	2.556	3.035
.255	.426	1.287	2.081	2.593	3.099
.260	.340	1.227	2.080	2.625	3.160
.265	.253	1.162	2.067	2.650	3.215
.270	.167	1.091	2.040	2.667	3.263
.275		1.015	1.996	2.672	3.301
.280		.933	1.930	2.663	3.327
.285		.845	1.840	2.636	3.336
.290		.751	1.720	2.590	3.327
.295		.650	1.567	2.519	3.294
.300		.542	1.374	2.420	3.235
.305		.426	1.138	2.288	3.145
.310		.301	.852	2.120	3.018
.315		.168	.509	1.909	2.851
.320			.104	1.650	2.636
.325				1.339	2.370
.330				.967	2.044
.335				.530	1.653
.340					1.189
.345					.645

N.	0.55	0.60	0.65	0.70	0.75
.085	1.615	1.685	1.780	1.839	1.933
.090	1.665	1.719	1.809	1.870	1.966
.095	1.714	1.754	1.840	1.904	2.001
.100	1.762	1.792	1.873	1.940	2.037
.105	1.809	1.833	1.910	1.980	2.075
.110	1.856	1.878	1.949	2.023	2.117
.115	1.903	1.927	1.993	2.071	2.163
.120	1.951	1.980	2.042	2.123	2.213
.125	1.999	2.039	2.095	2.180	2.268
.130	2.048	2.102	2.153	2.242	2.327
.135	2.098	2.170	2.216	2.310	2.391
.140	2.149	2.242	2.285	2.382	2.460
.145	2.201	2.320	2.358	2.460	2.534
.150	2.255	2.402	2.436	2.542	2.613
.155	2.311	2.489	2.518	2.629	2.697
.160	2.368	2.580	2.605	2.720	2.785
.165	2.426	2.675	2.696	2.815	2.878
.170	2.487	2.773	2.791	2.913	2.974
.175	2.548	2.873	2.889	3.015	3.073
.180	2.612	2.977	2.989	3.119	3.175
.185	2.676	3.082	3.092	3.224	3.279
.190	2.742	3.188	3.196	3.331	3.386
.195	2.808	3.295	3.301	3.439	3.493
.200	2.876	3.402	3.406	3.547	3.600
.205	2.943	3.508	3.511	3.653	3.708
.210	3.011	3.612	3.614	3.759	3.814
.215	3.079	3.714	3.716	3.862	3.919
.220	3.145	3.813	3.815	3.961	4.021
.225	3.211	3.908	3.910	4.058	4.120
.230	3.275	3.999	4.001	4.149	4.215
.235	3.336	4.084	4.087	4.235	4.305
.240	3.395	4.163	4.168	4.315	4.390
.245	3.450	4.235	4.241	4.388	4.468
.250	3.501	4.299	4.308	4.454	4.540
.255	3.548	4.355	4.366	4.511	4.603
.260	3.588	4.401	4.415	4.559	4.658
.265	3.622	4.437	4.454	4.597	4.704
.270	3.649	4.462	4.483	4.625	4.739
.275	3.667	4.476	4.501	4.641	4.764
.280	3.676	4.477	4.507	4.646	4.778
.285	3.675	4.465	4.500	4.639	4.779
.290	3.662	4.440	4.481	4.620	4.689
.295	3.636	4.401	4.448	4.587	4.745
.300	3.597	4.347	4.401	4.541	4.709
.305	3.542	4.278	4.340	4.481	4.658
.310	3.472	4.193	4.263	4.407	4.594
.315	3.383	4.093	4.171	4.319	4.515
.320	3.275	3.976	4.064	4.217	4.422
.325	3.146	3.842	3.941	4.101	4.314
.330	2.995	3.693	3.802	3.971	4.192
.335	2.820	3.526	3.647	3.826	4.055
.340	2.620	3.342	3.477	3.668	3.904
.345	2.392	3.142	3.290	3.497	3.739
.350	2.135	2.925	3.088	3.312	3.560
.355	1.846	2.691	2.870	3.116	3.368
.360	1.525	2.441	2.637	2.908	3.163
.365	1.169	2.176	2.390	2.689	2.946
.370	.776	1.895	2.129	2.460	2.718
.375	.343	1.599	1.855	2.222	2.479
.380		1.289	1.567	1.976	2.230
.385		.966	1.269	1.724	1.974
.390		.632	.959	1.468	1.710
.395		.285	.641	1.208	1.441
.400			.314	.946	1.167
.405				.685	.891
.410				.426	.615
.415				.172	.340
.420					
.425					

N.	0.80	0.90	1.00	1.25	1.50
.085	1.909	2.079	2.182	2.287	2.411
.090	1.948	2.128	2.237	2.353	2.479
.095	1.990	2.178	2.292	2.419	2.546
.100	2.034	2.229	2.348	2.484	2.613
.105	2.080	2.282	2.404	2.550	2.681
.110	2.130	2.336	2.462	2.616	2.749
.115	2.184	2.393	2.522	2.682	2.819
.120	2.242	2.452	2.583	2.750	2.889
.125	2.305	2.515	2.647	2.819	2.961
.130	2.372	2.580	2.713	2.888	3.035
.135	2.443	2.648	2.781	2.959	3.110
.140	2.519	2.719	2.852	3.032	3.187
.145	2.599	2.793	2.926	3.106	3.265
.150	2.684	2.871	3.002	3.182	3.345
.155	2.773	2.951	3.081	3.259	3.427
.160	2.866	3.034	3.162	3.338	3.510
.165	2.962	3.119	3.245	3.418	3.596
.170	3.061	3.207	3.330	3.500	3.682
.175	3.163	3.297	3.417	3.584	3.770
.180	3.268	3.389	3.506	3.668	3.860
.185	3.374	3.482	3.496	3.754	3.950
.190	3.481	3.576	3.687	3.841	4.042
.195	3.589	3.670	3.779	3.929	4.134
.200	3.696	3.765	3.871	4.018	4.227
.205	3.804	3.860	3.964	4.107	4.320
.210	3.910	3.954	4.056	4.197	4.413
.215	4.014	4.046	4.147	4.287	4.506
.220	4.115	4.137	4.237	4.377	4.598
.225	4.214	4.226	4.326	4.466	4.690
.230	4.308	4.313	4.413	4.555	4.781
.235	4.397	4.396	4.497	4.643	4.871
.240	4.482	4.475	4.579	4.730	4.959
.245	4.560	4.550	4.657	4.815	5.045
.250	4.631	4.620	4.732	4.899	5.129
.255	4.695	4.685	4.802	4.980	5.210
.260	4.751	4.745	4.868	5.059	5.288
.265	4.799	4.798	4.929	5.136	5.364
.270	4.837	4.844	4.984	5.209	5.435
.275	4.865	4.883	5.033	5.279	5.503
.280	4.883	4.915	5.076	5.346	5.567
.285	4.891	4.938	5.113	5.408	5.626
.290	4.886	4.953	5.142	5.466	5.681
.295	4.871	4.959	5.164	5.519	5.730
.300	4.843	4.956	5.178	5.567	5.774
.305	4.803	4.944	5.184	5.609	5.812
.310	4.750	4.921	5.181	5.646	5.844
.315	4.684	4.889	5.170	5.676	5.870
.320	4.605	4.846	5.150	5.700	5.889
.325	4.514	4.793	5.120	5.717	5.901
.330	4.409	4.730	5.082	5.727	5.906
.335	4.292	4.656	5.034	5.729	5.904
.340	4.161	4.571	4.976	5.724	5.894
.345	4.018	4.475	4.908	5.710	5.877
.350	3.863	4.370	4.831	5.688	5.851
.355	3.696	4.253	4.744	5.657	5.817
.360	3.518	4.127	4.647	5.616	5.775
.365	3.330	3.990	4.541	5.567	5.725
.370	3.131	3.845	4.425	5.507	5.666
.375	2.923	3.689	4.300	5.438	5.599
.380	2.707	3.526	4.166	5.358	5.522
.385	2.484	3.354	4.023	5.268	5.437
.390	2.255	3.174	3.872	5.168	5.344
.395	2.022	2.988	3.713	5.056	5.242
.400	1.785	2.795	3.547	4.933	5.131
.405	1.546	2.598	3.374	4.800	5.011
.410	1.307	2.396	3.194	4.654	4.883
.415	1.070	2.191	3.009	4.497	4.747
.420	.837	1.983	2.818	4.329	4.603
.425	.610	1.776	2.624	4.148	4.451

N.	1.75	2.00	2.50	3.00	4.00
.085	2.494	2.661	2.816	2.981	3.189
.090	2.569	2.739	2.904	3.071	3.286
.095	2.645	2.816	2.993	3.161	3.383
.100	2.720	2.893	3.081	3.250	3.480
.105	2.797	2.970	3.170	3.340	3.577
.110	2.874	3.047	3.259	3.430	3.674
.115	2.951	3.125	3.349	3.520	3.772
.120	3.030	3.203	3.439	3.611	3.871
.125	3.110	3.283	3.530	3.702	3.970
.130	3.191	3.363	3.621	3.794	4.069
.135	3.274	3.444	3.713	3.886	4.169
.140	3.358	3.527	3.806	3.979	4.269
.145	3.443	3.610	3.899	4.072	4.369
.150	3.529	3.695	3.992	4.166	4.470
.155	3.617	3.781	4.086	4.261	4.570
.160	3.705	3.868	4.180	4.355	4.671
.165	3.795	3.955	4.275	4.450	4.772
.170	3.886	4.044	4.369	4.545	4.873
.175	3.978	4.134	4.463	4.641	4.973
.180	4.070	4.224	4.558	4.736	5.073
.185	4.163	4.315	4.652	4.830	5.173
.190	4.257	4.406	4.745	4.925	5.272
.195	4.350	4.497	4.838	5.019	5.370
.200	4.444	4.589	4.930	5.112	5.467
.205	4.538	4.680	5.020	5.205	5.562
.210	4.631	4.771	5.110	5.296	5.657
.215	4.723	4.861	5.198	5.387	5.750
.220	4.815	4.951	5.285	5.476	5.841
.225	4.905	5.040	5.370	5.563	5.930
.230	4.994	5.127	5.453	5.649	6.017
.235	5.082	5.213	5.534	5.733	6.102
.240	5.168	5.297	6.613	5.815	6.185
.245	5.251	5.380	5.689	5.894	6.265
.250	5.332	5.460	5.762	5.971	6.342
.255	5.410	5.538	5.832	6.046	6.416
.260	5.486	5.612	5.900	6.118	6.487
.265	5.558	5.685	5.964	6.187	6.555
.270	5.627	5.753	6.025	6.252	6.620
.275	5.691	5.819	6.082	6.315	6.681
.280	5.752	5.881	6.136	6.374	6.739
.285	5.809	5.939	6.186	6.430	6.792
.290	5.861	5.992	6.232	6.482	6.842
.295	5.908	6.042	6.274	6.530	6.888
.300	5.950	6.087	6.312	6.574	6.930
.305	5.987	6.128	6.346	6.615	6.968
.310	6.019	6.163	6.376	6.652	7.002
.315	6.045	6.194	6.402	6.684	7.032
.320	6.065	6.219	6.423	6.713	7.057
.325	6.079	6.239	6.440	6.737	7.079
.330	6.087	6.254	6.453	6.757	7.096
.335	6.088	6.263	6.462	6.773	7.109
.340	6.084	6.267	6.467	6.786	7.118
.345	6.072	6.265	6.468	6.794	7.123
.350	6.054	6.257	6.465	6.798	7.124
.355	6.029	6.244	6.459	6.799	7.122
.360	5.998	6.225	6.449	6.796	7.116
.365	5.959	6.200	6.435	6.790	7.106
.370	5.914	6.170	6.419	6.780	7.093
.375	5.862	6.134	6.400	6.767	7.078
.380	5.803	6.093	6.378	6.751	7.059
.385	5.738	6.047	6.354	6.733	7.038
.390	5.666	5.996	6.329	6.712	7.015
.395	5.588	5.940	6.302	6.690	6.991
.400	5.503	5.879	6.274	6.666	6.964
.405	5.413	5.814	6.245	6.640	6.937
.410	5.316	5.745	6.217	6.614	6.909
.415	5.214	5.673	6.189	6.588	6.882
.420	5.106	5.597	6.162	6.562	6.854
.425	4.994	5.518	6.138	6.537	6.828

N.	5.00	7.50	10.00	12.50	15.00	N.	17.50	20.00	25.00	30.00
.085	3.323	3.555	3.753	3.920	4.073	.085	4.184	4.338	4.482	4.605
.090	3.424	3.664	3.868	4.044	4.196	.090	4.308	4.464	4.617	4.744
.095	3.526	3.774	3.983	4.170	4.320	.095	4.433	4.592	4.753	4.885
.100	3.628	3.885	4.100	4.296	4.444	.100	4.559	4.720	4.889	5.026
.105	3.730	3.996	4.217	4.422	4.569	.105	4.686	4.848	5.026	5.168
.110	3.833	4.107	4.334	4.549	4.694	.110	4.814	4.978	5.163	5.311
.115	3.936	4.219	4.526	4.676	4.820	.115	4.942	5.108	5.300	5.453
.120	4.039	4.331	4.571	4.803	4.946	.120	5.071	5.238	5.437	5.596
.125	4.143	4.444	4.690	4.930	5.072	.125	5.201	5.368	5.575	5.738
.130	4.248	4.557	4.810	5.057	5.198	.130	5.331	5.499	5.712	5.880
.135	4.352	4.670	4.929	5.183	5.323	.135	5.461	5.629	5.849	6.022
.140	4.457	4.782	5.049	5.309	5.449	.140	5.591	5.760	5.985	6.163
.145	4.562	4.895	5.168	5.435	5.574	.145	5.721	5.890	6.120	6.303
.150	4.667	5.008	5.287	5.559	5.699	.150	5.852	6.020	6.255	6.442
.155	4.772	5.120	5.406	5.683	5.823	.155	5.981	6.149	6.389	6.580
.160	4.876	5.232	5.525	5.805	5.946	.160	6.110	6.278	6.522	6.716
.165	4.981	5.344	5.643	5.927	6.068	.165	6.239	6.406	6.653	6.851
.170	5.085	5.455	5.760	6.047	6.189	.170	6.367	6.533	6.783	6.985
.175	5.189	5.565	5.876	6.165	6.309	.175	6.493	6.659	6.911	7.116
.180	5.293	5.674	5.991	6.282	6.428	.180	6.619	6.783	7.038	7.246
.185	5.395	5.782	6.105	6.398	6.546	.185	6.743	6.907	7.163	7.374
.190	5.497	5.889	6.218	6.511	6.661	.190	6.865	7.028	7.286	7.499
.195	5.597	5.995	6.329	6.622	6.775	.195	6.986	7.148	7.407	7.622
.200	5.697	6.099	6.439	6.732	6.888	.200	7.105	7.266	7.526	7.743
.205	5.795	6.201	6.546	6.839	6.998	.205	7.222	7.382	7.642	7.861
.210	5.891	6.302	6.652	6.944	7.106	.210	7.337	7.496	7.756	7.976
.215	5.986	6.401	6.756	7.046	7.212	.215	7.449	7.608	7.867	8.089
.220	6.080	6.498	6.857	7.146	7.316	.220	7.558	7.717	7.976	8.198
.225	6.171	6.592	6.956	7.243	7.417	.225	7.665	7.823	8.082	8.305
.230	6.260	6.684	7.053	7.337	7.516	.230	7.768	7.927	8.185	8.408
.235	6.346	6.774	7.147	7.429	7.612	.235	7.869	8.028	8.285	8.509
.240	6.431	6.861	7.238	7.517	7.705	.240	7.966	8.126	8.381	8.606
.245	6.512	6.945	7.326	7.602	7.795	.245	8.060	8.220	8.475	8.699
.250	6.591	7.027	7.411	7.684	7.882	.250	8.150	8.312	8.565	8.790
.255	6.667	7.105	7.493	7.763	7.966	.255	8.237	8.400	8.652	8.876
.260	6.740	7.180	7.572	7.839	8.047	.260	8.320	8.484	8.736	8.959
.265	6.810	7.252	7.647	7.911	8.124	.265	8.398	8.565	8.816	9.039
.270	6.877	7.321	7.719	7.980	8.198	.270	8.473	8.642	8.892	9.115
.275	6.940	7.386	7.877	8.045	8.269	.275	8.543	8.715	8.965	9.187
.280	6.999	7.448	7.851	8.107	8.336	.280	8.609	8.785	9.034	9.255
.285	7.055	7.506	7.912	8.165	8.400	.285	8.671	8.850	9.099	9.320
.290	7.107	7.561	7.969	8.219	8.459	.290	8.728	8.911	9.160	9.380
.295	7.156	7.611	8.022	8.270	8.515	.295	8.781	8.968	9.218	9.437
.300	7.200	7.658	8.071	8.317	8.568	.300	8.829	9.021	9.271	9.490
.305	7.241	7.701	8.116	8.361	8.616	.305	8.872	9.070	9.321	9.539
.310	7.277	7.740	8.157	8.400	8.661	.310	8.911	9.115	9.367	9.584
.315	7.310	7.776	8.194	8.437	8.702	.315	8.945	9.155	9.409	9.626
.320	7.339	7.807	8.226	8.469	8.739	.320	8.975	9.191	9.447	9.663
.325	7.363	7.835	8.255	8.498	8.772	.325	9.000	9.223	9.482	9.697
.330	7.384	7.858	8.280	8.523	8.802	.330	9.020	9.250	9.512	9.727
.335	7.400	7.878	8.301	8.545	8.827	.335	9.036	9.274	9.538	9.753
.340	7.413	7.894	8.318	8.563	8.849	.340	9.047	9.293	9.561	9.775
.345	7.422	7.907	8.331	8.577	8.867	.345	9.054	9.308	9.580	9.793
.350	7.426	7.915	8.341	8.589	8.882	.350	9.056	9.318	9.595	9.809
.355	7.428	7.921	8.347	8.597	8.893	.355	9.055	9.325	9.607	9.820
.360	7.426	7.923	8.349	8.602	8.900	.360	9.049	9.328	9.614	9.828
.365	7.420	7.921	8.348	8.603	8.904	.365	9.040	9.327	9.619	9.832
.370	7.411	7.917	8.343	8.602	8.905	.370	9.027	9.323	9.620	9.834
.375	7.399	7.909	8.335	8.598	8.902	.375	9.010	9.315	9.618	9.832
.380	7.384	7.899	8.325	8.592	8.897	.380	8.991	9.304	9.612	9.827
.385	7.367	7.886	8.311	8.583	8.888	.385	8.968	9.289	9.603	9.819
.390	7.348	7.871	8.295	8.571	8.877	.390	8.943	9.272	9.592	9.808
.395	7.326	7.854	8.277	8.558	8.864	.395	8.915	9.251	9.577	9.794
.400	7.302	7.835	8.257	8.542	8.848	.400	8.886	9.229	9.560	9.778
.405	7.278	7.815	8.235	8.525	8.829	.405	8.854	9.204	9.541	9.759
.410	7.252	7.793	8.212	8.506	8.809	.410	8.821	9.177	9.519	9.738
.415	7.226	7.771	8.187	8.486	8.787	.415	8.788	9.148	9.495	9.715
.420	7.199	7.748	8.162	8.465	8.765	.420	8.754	9.118	9.469	9.690
.425	7.173	7.725	8.136	8.444	8.740	.425	8.720	9.086	9.442	9.663

[a] Expressed as moles percent cholesterol (cholesterol × 100/bile salt plus lecithin plus cholesterol) at equilibrium.
[b] N. represents the molar lecithin/bile salt plus lecithin ratio in bile.
[c] Values appearing as numbers of larger size at the tops of the columns represent the total lipid concentration (bile salt plus lecithin plus cholesterol) expressed in g/dl of bile.

saturate bile at equilibrium as a function of both total lipid concentration (in g/dl) and molar [lecithin]/[bile salt] + [lecithin] ratio.

USE OF TABLES

The data in Table 1 are organized in a similar fashion to the mantissae of common logarithms. The column of numbers on the far left of each page denoted by *N.* represents the molar [lecithin]/[bile salt] + [lecithin] ratio. (In dilute bile the reduced capacity to solubilize lecithin (3) is reflected by the shorter columns.) In practice, this ratio may be calculated numerically from the analytical relative lipid composition of bile expressed in moles percent total moles employing molecular weights of 491 for mixed bile salts, 775 for biliary lecithin, and 387 for anhydrous cholesterol. For most human bile samples the value of *N.* varies between 0.100 and 0.400 (see Table 2); however, the tables are extended slightly to encompass molar ratios found in certain animal biles. At the top of each column the appropriate total lipid concentration (in g/dl) is represented in numbers of larger size. The range varies from 0.30 g/dl to 30 g/dl in the following increments, 0.05 g/dl (0.30–0.80 g/dl), 0.1 g/dl (0.80–1.0 g/dl), 0.25 g/dl (1.0–2.0 g/dl), 0.5 g/dl (2.0–3.0 g/dl), 1.0 g/dl (3.0–5.0 g/dl), 2.5 g/dl (5.0–20.0 g/dl), and 5.0 g/dl (20.0–30.0 g/dl). This arrangement was necessary to provide approximate arithmetic increments in moles percent cholesterol since the relationship between cholesterol solubility and the total lipid concentration is semilogarithmic. In an individual bile sample, the total lipid concentration is the arithmetic sum of the analytical lipid concentrations (bile salt plus lecithin plus cholesterol) expressed in g/dl of bile.

To find the moles percent cholesterol at saturation in a bile sample when the molar [lecithin]/[bile salt] + [lecithin] ratio and total lipid concentration correspond *exactly* to the tabulated parameters of the table, one only needs to take out from the appropriate total lipid concentration column the three decimal place value for moles percent cholesterol on a line with the appropriate molar [lecithin]/[bile salt] + [lecithin] ratio. By dividing this number into the moles percent cholesterol actually present in the bile sample (from the analytical relative lipid composition in moles per 100 moles) one derives the lithogenic index of Metzger, Heymsfield, and Grundy (1), which is defined as the molar ratio of cholesterol actually present to the maximal amount that would be soluble at equilibrium at the total lipid concentration and bile salt–lecithin ratio of the sample. When multiplied by 100 this index is identical to Redinger and Small's (2) percent cholesterol saturation which is hereafter employed in this paper for numerical convenience.

However, to find the moles percent cholesterol at saturation when the molar [lecithin]/[bile salt] + [lecithin] ratio and total lipid concentration of a bile sample *do not* correspond to the tabulated parameters of the table, interpolation only in the case of the total lipid concentration should be employed. (No loss of precision is entailed by employing the closest value for the former, see below.) Thus take out of the table on a line with the closest molar [lecithin]/[bile salt] + [lecithin] ratio *both values* for moles percent cholesterol corresponding to total lipid concentrations immediately above and below that of the bile sample. Then divide the difference between these two values by the corresponding difference in total lipid concentration and multiply the result by the difference in g/dl between that of the actual bile sample and either the upper or lower value for total lipid concentration. The number obtained represents the proportional part that must be added to or subtracted from one of the tabulated mole percent cholesterol values in order to obtain the correct interpolated value appropriate to the bile sample. EXAMPLE: A bile sample has a molar [lecithin]/[bile salt] + [lecithin] ratio of 0.248 and total lipid concentration of 5.9 g/dl. To find the correct moles percent cholesterol value, employ the closest molar ratio (*N.* value) of 0.250 and take out from that line in the table moles percent cholesterol values of 6.591 and 7.027, which correspond to total lipid concentrations of 5 and 7.5 g/dl respectively. To obtain the proportional part one calculates

$$\frac{7.027 - 6.591}{2.5} \times 0.9 = 0.157$$

which when added to 6.591 gives the correct value of 6.748 for a total lipid concentration of 5.9 g/dl. Alternatively, one can deduce the above result by subtracting an appropriate proportional part from the larger value for moles percent cholesterol, e.g.,

$$\frac{7.027 - 6.591}{2.5} \times 1.6 = 0.279$$

which when substracted from 7.027 gives an identical value of 6.748. The lithogenic index or percent cholesterol saturation is then calculated in the usual way.

PRECISION OF TABLES

The standard error about the curves (Fig. 1) varies from 0.1 to 0.3 depending on the total lipid concentration (3). In general the closeness of fit of observed (experimental) and predicted (from the polynomial regression) data gives a maximum error of 1% for moles percent cholesterol with total lipid concentrations of 2.5 g/dl and greater and a maximum error of 3% with total lipid concentration less than 2.5 g/dl but greater than 1 g/dl (3). Tables 2–5 give a comparison of calculated percent cholesterol saturation values for a series of gallbladder and common hepatic duct biles from cholesterol gallstone patients and control subjects without stones (recalculated from Ref. 3) *1*) utilizing hand measurements from the triangular coordinate graphs with visually interpolated cholesterol solubility limits for the precise total lipid concentration in each sample; *2*) by solving the fifth degree polynomial equation (3) computed for a total lipid concentration closest to that of each sample; *3*) from the critical tables in this work with interpolations as described above for the precise total lipid concentration but employing the closest molar [lecithin]/[bile salt] + [lecithin] ratio to that of the sample (sample interpolations show that by approximating the latter the maximal errors are well within the standard errors of the curves, ≃0.5%); and *4*) from the critical tables assuming only "average" cholesterol solubility values for a *fixed* total lipid concentration of 10 g/dl. The results were tested statistically using the paired *t* test of Student. There is remarkably good agreement between the values for percent cholesterol saturation derived by the polynomial regression (in

TABLE 2. Gallbladder biles: cholesterol gallstone patients

				Percent Cholesterol Saturation[d] from:			
Sample	Cholesterol %[a]	Lec / (BS + Lec)[b]	Total Lipid[c] Concentration	Triangular Graphs[e] (5.0–18.0 g/dl)	Polynomial Eq.[f] (5.0–18.0 g/dl)	Critical Tables (5.0–18.0 g/dl)	Critical Tables[g] (10 g/dl)
1	8.9	0.179	7.8	159	158	153	149
2	10.0	0.260	12.8	130	128	127	132
3	9.0	0.191	17.0	130	131	131	145
4	12.9	0.242	7.3	184	184	189	178
5	7.2	0.242	6.4	111	105	108	100
6	8.1	0.213	13.6	114	116	114	120
7	7.3	0.215	9.1	112	108	110	108
8	8.0	0.234	16.2	105	105	103	112
9	7.1	0.182	10.2	118	118	118	119
10	9.4	0.266	5.6	136	138	136	123
11	9.7	0.199	18.0	137	137	136	151
12	12.7	0.310	11.3	151	151	153	156
13	7.3	0.318	5.0	101	100	100	89
14	8.5	0.228	8.0	129	128	126	121
15	11.8	0.222	16.6	159	155	158	172
16	8.9	0.205	10.4	139	136	135	136
Mean			10.9	132%	131%	131%	132%

(See *h* and *i*) [Triangular Graphs vs. Polynomial Eq.]
(See *j*) [Triangular Graphs vs. Critical Tables (5.0–18.0 g/dl)]
(See *k*) [Triangular Graphs vs. Critical Tables (10 g/dl)]
(See *l*) [Critical Tables (5.0–18.0 g/dl) vs. Critical Tables (10 g/dl)]

[a] Expressed in moles per 100 moles of total lipids.
[b] Molar [lecithin]/[bile salt] + [lecithin] ratios.
[c] Expressed in g/dl of bile.
[d] Calculated as described in ref. 2 and in present text.
[e] Published in ref. 3.
[f] Published in ref. 3.
[g] This column is tabulated to demonstrate the errors in calculating percent cholesterol saturation values when variations in total lipid concentration are ignored.
[h] Data tested statistically using paired *t* test of Student; N.S., not significant.
[i] $t = 1.902$; $0.05 < P > 0.025$; mean error 0.8% (range 0–5%).
[j] $t = 1.745$, N.S.; mean error 0.8% (range 0–4%).
[k] $t = 0.078$, N.S.; mean error 0% (range 1–12%).
[l] $t = 0.379$, N.S.; mean error 0.8% (range 1–11%).

TABLE 3. Gallbladder biles: control subjects without stones

Sample	Cholesterol %[a]	Lec/(BS + Lec)[b]	Total Lipid[c] Concentration	Percent Cholesterol Saturation[d] from: Triangular Graphs[e] (8.7–24.9 g/dl)	Polynomial Eq.[f] (8.7–24.9 g/dl)	Critical Tables (8.7–24.9 g/dl)	Critical Tables[g] (10 g/dl)
1	3.3	0.108	9.8	79	77	77	76
2	7.1	0.170	11.3	120	117	120	124
3	2.3	0.230	12.7	30	31	31	33
4	7.8	0.250	24.9	93	91	91	105
5	10.9	0.292	12.2	131	132	133	137
6	7.5	0.221	20.2	97	97	97	109
7	4.6	0.218	17.3	61	61	61	67
8	6.1	0.206	12.3	90	89	90	93
9	8.9	0.297	12.9	105	107	107	111
10	6.0	0.176	8.7	105	107	105	102
11	7.8	0.159	17.1	130	128	128	141
12	8.0	0.254	19.1	97	95	96	107
Mean			14.9	95%	94%	95%	100%

(See *h* and *i*) — Triangular Graphs vs. Polynomial Eq.

(See *j*) — Triangular Graphs vs. Critical Tables (8.7–24.9 g/dl)

(See *k*) — Triangular Graphs vs. Critical Tables (10 g/dl)

(See *l*) — Critical Tables (8.7–24.9 g/dl) vs. Critical Tables (10 g/dl)

[a–h] See Table 2.
[i] $t = 1.00$, N.S.; mean error 1% (range 0–3%).
[j] $t = 0.411$, N.S.; mean error 0% (range 0–3%).
[k] $t = 3.74$; $P < 0.0025$; mean error 5% (range 3–13%).
[l] $t = 3.58$; $P < 0.0025$; mean error 5% (range 3–15%).

spite of approximating the total lipid concentration), from the critical tables (for precise total lipid concentrations), and by the triangular graph method (also for precise total lipid concentrations) and, in general, the differences were not statistically significant. When only the critical tables (or, for that matter, the polynomial regression or triangular coordinate graphs) are employed on the assumption that all bile samples approximate a single total lipid concentration of 10 g/dl, the errors in the calculated percent cholesterol saturation values are large and increase in proportion to the magnitude of deviation of the *actual* from the *assumed* total lipid concentration value (i.e., 10 g/dl). For example, with gallbladder biles from cholesterol gallstone patients (**Table 2**) the mean error in the calculated percent cholesterol saturation values using the critical tables for 10 g/dl is zero as the mean total lipid concentration of the group corresponds to 10.9 g/dl; however, the range for individual biles is 1–12%. As expected, the difference between each pair of data is not statistically significant with the exception of the comparison between the triangular graph and polynomial equation methods where the difference is marginally significant at the 5% level. In the case of gallbladder biles from control subjects (**Table 3**), no significant differences are found in percent cholesterol saturation values derived by the triangular graph, polynomial equation, or critical table methods. However, the results by the critical table method for a constant 10 g/dl total lipid concentration are significantly different ($P < 0.0025$) from the others, reflecting the fact that the mean total lipid concentration of the samples was 14.9 g/dl and not 10 g/dl. This corresponds to a 5% error (range 3–15%). In the case of more dilute hepatic duct biles (**Tables 4 and 5**) the triangular graph, polynomial equation, and critical tables for variations in total lipid concentration give percent cholesterol saturation values that are not statistically different from one another. With the use of the critical tables for a 10 g/dl total lipid concentration, large errors (20%, range 4–32%) result and the differences from the percent cholesterol saturation values by the other methods are statistically significant. Once again the differences reflect the fact that the mean total lipid concentrations of these biles were 3.4 and 3.9 g/dl and not 10 g/dl. The use of moles percent cholesterol values for an average 10 g/dl total lipid concentration for the calculation of the percent cholesterol saturation of very dilute (<1 g/dl) hepatic biles can, as might be expected, lead to very large errors. For example, the total lipid concentration of two hepatic biles in our patients was 0.6 g/dl (data not tabulated). Calculation of percent cholesterol saturation based on the 10 g/dl total lipid concentration data results in individual errors of 52%. It is obvious that errors of

TABLE 4. Common hepatic duct biles: cholesterol gallstone patients

Sample	Cholesterol %[a]	Lec / (BS + Lec)[b]	Total Lipid[c] Concentration	Percent Cholesterol Saturation[d] from: Triangular Graphs[e] (1.5–7.9 g/dl)	Polynomial Eq.[f] (1.5–7.9 g/dl)	Critical Tables (1.5–7.9 g/dl)	Critical Tables[g] (10 g/dl)
1	11.6	0.225	3.1	211	209	207	167
2	21.7	0.302	1.5	380[i]	375	376	269
3	8.3	0.183	5.9	151	155	150	136
4	16.5	0.291	3.4	243	254	250	207
5	12.5	0.237	1.9	240	238	242	175
6	13.0	0.309	2.4	197	204	205	159
7	6.9	0.215	7.9	106	108	107	102
8	19.1	0.317	1.8	310	317	316	234
9	7.6	0.214	4.0	135	133	132	113
10	18.3	0.321	3.2	265	272	267	222
11	19.6	0.357	2.8	293[i]	288	294	235
Mean			3.4 g/dl	230%	232%	232%	184%

(See h and j) — Triangular Graphs vs. Polynomial Eq.
(See k) — Triangular Graphs vs. Critical Tables (1.5–7.9 g/dl)
(See l) — Triangular Graphs vs. Critical Tables (10 g/dl)
(See m) — Critical Tables (1.5–7.9 g/dl) vs. Critical Tables (10 g/dl)

[a–h] See Table 2.
[i] Revised (see ref. 3).
[j] $t = 1.20$, N.S.; mean error 0.9% (range 0.6–5%).
[k] $t = 1.06$, N.S.; mean error 0.9% (range 0.3–4%).
[l] $t = 5.12$; $P < 0.0005$; mean error 20% (range 4–27%).
[m] $t = 5.28$; $P < 0.0005$; mean error 20% (range 5–28%).

such magnitude can lead to erroneous conclusions concerning the "lithogenicity" or unsaturation of bile in individual patients. The possible clinical implications of the differences in the correct mean percent cholesterol saturation values between gallstone patients and controls (Tables 2–5) are discussed elsewhere (3). We must caution, however, that in the case of total lipid concentrations less than 1 g/dl, the use of both the polynomial equations and the critical tables can give rise to appreciable errors (as high as 15%) in the calculated percent cholesterol saturation values. This arises from the fact that the computed curves for very dilute (<1 g/dl) bile are intrinsically imprecise as mathematical difficulties were encountered in

TABLE 5. Common hepatic duct biles: control subjects without stones

Sample	Cholesterol %[a]	Lec / (BS + Lec)[b]	Total Lipid[c] Concentration	Percent Cholesterol Saturation[d]: Triangular Graphs[e] (1.4–4.2 g/dl)	Polynomial Eq.[f] (1.4–4.2 g/dl)	Critical Tables (1.4–4.2 g/dl)	Critical Tables[g] (10 g/dl)
1	10.8	0.265	1.4	208	202	205	141
2	18.0	0.345	2.3	281	278	270	216
3	4.8	0.222	2.2	92	96	94	70
4	12.0	0.276	4.2	174	179	178	154
5	10.1	0.297	4.1	140	146	146	126
6	7.5	0.192	3.7	143	141	145	121
Mean			3.9	173%	174%	173%	138%

(See h and i) — Triangular Graphs vs. Polynomial Eq.
(See j) — Triangular Graphs vs. Critical Tables (1.4–4.2 g/dl)
(See k) — Triangular Graphs vs. Critical Tables (10 g/dl)
(See l) — Critical Tables (1.4–4.2 g/dl) vs. Critical Tables (10 g/dl)

[a–h] See Table 2.
[i] $t = 0.329$, N.S.; mean error 0.6% (range 1–4%).
[j] $t = 0$, N.S.; mean error 0% (range 1–4%).
[k] $t = 3.54$; $0.01 < P > 0.005$; mean error 20% (range 8–32%).
[l] $t = 4.53$; $0.0025 < P > 0.0005$; mean error 20% (range 14–31%).

TABLE 6. Comparison of mole percent cholesterol values from this work and H-D-H[a] data

$\frac{Lec^b}{BS + Lec}$	This Work[c]	H-D-H Data[a]	Percent Error in H-D-H Data
0.100	4.100	3.967	−3.2
0.125	4.690	4.410	−6.0
0.150	5.287	4.903	−8.2
0.175	5.876	5.428	−7.6
0.200	6.439	5.964	−7.4
0.225	6.956	6.492	−6.7
0.250	7.411	6.994	−5.6
0.275	7.787	7.451	−4.3
0.300	8.071	7.842	−2.8
0.325	8.255	8.149	−1.3
0.350	8.341	8.352	+0.1
0.375	8.335	8.433	+1.2
0.400	8.257	8.372	+1.4
0.425	8.136	8.150	+0.2

$t = 3.77^d$

$0.0025 < P > 0.0005$

[a] Using the Thomas–Hofmann polynomial (7) derived for pooled data of Hegardt and Dam (9) and Holzbach et al. (8).
[b] Molar [lecithin]/[bile salt] + [lecithin] ratio.
[c] Using critical tables (Table 1) for a total lipid concentration of 10 g/dl.
[d] Data tested statistically using the paired t test of Student.

fitting fifth degree polynomial regressions to the cholesterol solubility limits of very small micellar zones. Even though total lipid concentrations less than 1 g/dl are infrequent in man (although found commonly in small animals), the tables can still be used to obtain the approximate percent cholesterol saturation values but, when possible, these should be verified by hand measurements from the appropriate triangular coordinate graphs published elsewhere (3).

In **Table 6**, representative values for moles percent cholesterol derived from the equation of Thomas and Hofmann (7) to describe the pooled data of Holzbach, Marsh, and Olszewski (8) and Hegardt and Dam (9) are compared with values from this work (Table 1) for a 10 g/dl total lipid concentration. The errors in the two sets of data are statistically significant ($0.0025 < P > 0.0005$) particularly at high bile salt–lecithin ratios, i.e., molar [lecithin]/[bile salt] + [lecithin] ratios of 0.100–0.300, but agreement is good at higher ratios. In their experiments, Hegardt and Dam (9) did not control for total lipid concentration (interexperimental variation of 5–12 g/dl) and assayed the micellar mixtures for cholesterol only, and Holzbach et al. (8) carried out their study in H_2O (no added NaCl) at an uncertain final total lipid concentration as the analyzed micellar mixtures were the filtrates of supersaturated mixtures that contained total lipid concentrations of 10 g/dl. We have discussed elsewhere (3) that all of these factors will underestimate the maximum cholesterol solubility (mole percent cholesterol) at high bile salt–lecithin ratios as demonstrated in Table 6.

CONCLUSIONS

The solubility of cholesterol in conjugated bile salt–lecithin–cholesterol systems in 0.15 M NaCl at 37°C increases in a semi-logarithmic fashion with increases in total lipid concentration at a constant bile salt–lecithin ratio. A family of curves delineating the limits of cholesterol solubility in bile as a function of physiological bile salt–lecithin ratios and total lipid concentrations were accurately fitted by fifth degree polynomial regressions and plotted in rectangular format relating moles percent cholesterol, [cholesterol] × 100/[bile salt] + [lecithin] + [cholesterol], to the molar [lecithin]/[bile salt] + [lecithin] ratio. We solved all of these equations for moles percent cholesterol using values of molar [lecithin]/[bile salt] + [lecithin] ratio of 0.085 to 0.425 as a function of total lipid concentration between 0.30 g/dl and 30 g/dl and employed these results to obtain the percent cholesterol saturation of gallbladder and hepatic biles from gallstone patients and controls. The results have led to two general conclusions concerning the procedure for calculating the lithogenic index or percent cholesterol saturation of bile. First, both the bile salt–lecithin ratio *and* total lipid concentration are two fundamental but independent variables which must be mutually considered in the determinations of the maximum equilibrium cholesterol solubility (expressed as moles percent cholesterol) in any native bile sample. Thus the use of the tables facilitates the derivation of correct values for moles percent cholesterol and therefore the rapid and accurate calculation of lithogenic index (or percent cholesterol saturation) of native bile samples (human or animal), provided the total and relative lipid concentrations are known. Second, the Thomas–Hofmann (7) polynomial or the combined data of Hegardt and Dam (9) and Holzbach et al. (8) upon which it is based should only be utilized to calculate an *approximate* lithogenic index (or percent cholesterol saturation) for a single biliary total lipid concentration in the vicinity of 8–10 g/dl. When compared with data in the present work, numerical solution of the Thomas–Hofmann polynomial for a physiological range of bile salt–lecithin ratios results in errors as large as 8% in moles percent cholesterol, particularly at high bile salt–lecithin ratios. These discrepancies are due to lack of attention to the importance of total lipid concentration and physiological ionic strength in the experimental determination of the cholesterol solubility of bile in previous studies.

APPENDIX

Aqueous solutions of taurine and glycine conjugates of lithocholate and lithocholate sulfate at concentrations well above their critical micellar temperatures and critical micellar concentrations have no capacity to solubilize cholesterol and a negligible ability to solubilize lecithin.[4] When compared with the common conjugated bile salts, the maximal solubility of cholesterol in ursodeoxycholate conjugates is insignificant (~1:500 molar ratio) in the absence of lecithin and is much reduced even with physiological lecithin concentrations (10). As ursodeoxycholic acid is increasingly employed for gallstone dissolution in man, we have studied the influence of varying concentrations of tauroursodeoxycholate and glycoursodeoxycholate on equilibrium cholesterol solubility in model systems of taurochenodeoxycholate–lecithin and glycochenodeoxycholate–lecithin, respectively, in 0.15 M NaCl at 37°C (total lipid concentration, 10 g/dl), pH 7.0 (taurine conjugate), pH 9–10 (glycine conjugates). Our results indicate that over the physiological range of [lecithin]/[bile salt] + [lecithin] molar ratios (0.1–0.5) the decrease in cholesterol solubility is linearly related to the tauroursodeoxycholate or glycoursodeoxycholate content (expressed as percent of total bile salts) in the micellar mixture. The cholesterol solubility in these model systems is reduced much more by the glycine conjugate than by the taurine conjugate ($P < 0.0005$) and the reduction is strikingly independent of the bile salt–lecithin ratio. In the case of the taurine series, the moles percent cholesterol solubilized is reduced by 0.0218 (range 0.018–0.024) for each percent tauroursodeoxycholate present and, in the case of the glycine series, the moles percent cholesterol solubilized is reduced by 0.0412 (range 0.037–0.044) for each percent glycoursodeoxycholate present. The weighted average for a 4:1 glycine-, taurine-conjugated bile salt molar ratio typical of bile is thus 0.037. Our calculations therefore indicate that, in order to correct the moles percent cholesterol values in Table 1 for the effect of ursodeoxycholate conjugates in bile, the correction factor 0.037 must be multiplied by the percent of ursodeoxycholate conjugates in the total bile acids and the product subtracted from the appropriate tabulated or interpolated values for moles percent cholesterol before the lithogenic index or percent cholesterol saturation is calculated. At present this correction factor is valid only for a total lipid concentration of 10 g/dl.

[4] Carey, M. C. and G. Ko. Unpublished observations.

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